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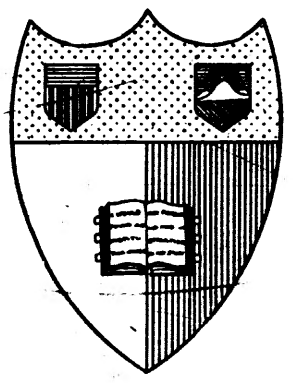
Second Edition



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Natural History of the Honeybee

or

Are Bees Reflex Machines?

By

H. v. Buttel-Reepen, Ph. D.

Translated by Mary H. Geisler

Second Edition

THE A. I ROOT COMPANY
Medina, Ohio, U S. A.
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A translation of "Sind die Bienen Reflex-machinen?" by Dr. H. v. Buttel-Reepen. This paper first appeared in the "Biologischen Centralblatt," Vol. XX., 1900, and was reprinted, with the addition of a table of contents and index, in the same year by Arthur Georgi, of Leipsig. Footnotes in this English edition which are marked "E. F. P." are by Dr. E. F. Phillips, United States Department of Agriculture.

TABLE OF CONTENTS.

INTRODUCTION 1
THE HIVE ODOR AND THE REACTIONS RESULTING FROM IT 4
Modification of Reactions toward the Hive Odor 5
The Swarming-out of a Queenless Colony 5
Intensifying the Reaction 6
Overcoming the Reactions toward Hive Odor 6
The Odor of the Queen 7
The Brood Odor 9
The Indifferent Odor of Young Bees 9
Failure of the Hive-odor Reactions in Queens and Drones 10
Abnormal Hive Odor 10
THE MEANS OF COMMUNICATION IN BEES 12
Investigations with Colonies from which the Queens are Taken 12
Behavior of a Queenless Swarm 14
Disregard of a Queen in Open Air 14
Hearing Capacity and Sensations of Sound Present 15
Experiments on Swarms 15
The Infecting Influence of the Swarm-tone 16
The Enticing Note of Bees 16
The "Teeting" and "Quahking" of a Queen 17
The Queen's Tone of Fear 17
MEMORY OF PLACE IN BEES 19
The "Paths" of Bees and their Direction 19
Disappearance of the Memory for Location through Narcotization 23
The Box Experiment 23
The Loss of Memory for Location through Swarm Dizziness, etc 27
Associations of Impressions 28
Memory for the Feeding-place in the Hive 28
Conduct of Bees in the Buckwheat Season 29
Are Bees Attracted by the Color of Flowers or by the Nectar? 29
Place Perception in the Queen 29
Memory for Locality in Scouting Bees 30
The Eyes of Bees 32
The Flight of Orientation 32
The Finding of the Hive through the Senses of Sight and Smell 33
Bethe's Tree Experiment 34
Special Capacity for Orientation in Bees 36
The Influence of Weather Conditions on the Sense of Sight, therefore on the Ability to Orient 37
Influence of Color on Bees 38
SOME FURTHER CONTRIBUTIONS TO THE NATURAL HISTORY 40
The Flight of Bees into a Room 40
The Behavior of Robbing Bees 41
The Origin of Hostile Conduct 40
The Vanishing of Instincts with the Decrease in the Strength of a Colony 41
Reactions toward Flight 41
The Formation of the Honey-comb 42
The Play Instinct in Bees 43
CONCLUSIONS 44
BIBLIOGRAPHY 46

INTRODUCTION.

The following observations are submitted after fifteen years' study, and are further to be used for a General Biology of the Honey-bee; but this larger work can not be completed until later, because of the heavy demands on my time at present. It seems desirable to publish this much of the investigation now, however, and I wish specially to consider the most vigorously debated question of the day, that of the psychical faculties of social insects, because of Bethe's [1] interesting study of this question with regard to ants and bees. I shall take up bees only, as there are many scientific observations on ants [2] and as especially the great myrmicologists Aug. Forel [3] and Wasmann [2] have already overthrown many of Bethe's conclusions.

That I do not accept Wasmann's definition of Instinct will be apparent from what follows. I refer to the discussion of instincts in my "Stammesgeschichtlichen Entstehung der Bienenstaates, Leipzig, 1903, as well as to Forel's excellent paper, "Gehirn und Seele," 5. u. 6. Aufl., Bonn, 1899, pp. 34 and following.

As early as 1872, Dohrn [4] recognized that it would benefit science if more biological [5] investigation were carried on, and the results made useful practically. It seems to me that the biological knowledge concerning *Apis mellifica* [6] which has been gained by practical bee-keeping has scarcely entered scientific literature, and, strangely enough, the results are little regarded; it has not passed over into the flesh and blood of science. In proof

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[1] Albrecht Bethe, Durfen wir Ameisen und Bienen psychische Qualitaten zuschreiben? Arch. f. die ges. Physiologie, Bd. 79, 1898. (Also appears as a separate with other paging.)

[2] Wasmann, Die psychischen Fahigkeiten der Ameisen. Stuttgart, Erwin Negele, 1899.

[3] Forel, Fourmis de la Suisse. Nouveaux mémoires de la société Helvétique. Zurich, 1874. Expériences et remarques critiques sur les sensations des Insectes. Rivista di Scienze Biologiche. Como, 1900, 1901. The Psychical Faculties of Ants and some Other Insects. Smithsonian Report for 1903, pp. 587-599. Washington, 1904, etc.

Lubbock. Ants, Bees, and Wasps. International Scientific Series. New York, 1883; German translation, Leipzig, 1883.

Janet. Études sur les Fourmis, les Guepes, et les Abeilles. Limoges, 1897, etc.

Emery. Die Entstehung und Ausbildung des Arbeiterstandes bei den Ameisen, Ueber Entstehung des Soziallebens bei Hymenopteren. Biol. Centralbl., Bd. XVI., 1894. Le Polymorphisme des Fourmis et l' alimentaire. Compt. rend. III. Congr. internat. d. Zool. Leyden, 1896, etc.

Wm. Morton Wheeler. The Compound and Mixed Nests of American Ants. American Naturalist, Vol. XXXV., 1901. Some Remarks on Temporary Social Parasitism and the Phylogeny of Slavery among Ants. Biolog. Centralbl., 1905. Ethological Observations on an American Ant. Journal fur Psychologie und Neurologie. Leipzig, 1903, etc. K. Escherich. Die Ameise. Braunschweig, 1906.

Bethe, l. c.

[4] A. Dohrn. Der gegenwartige Stand der Zoologie, etc.: XXX. Bd. Preuss. Jahrb., 1872.

[5] The German word *Biologie* refers particularly to the study of life-history and habits rather than to all phases of animal and plant life—the sense in which it is used in English.—E. F. P.

[6] *Apis mellifica* L., or *Apis mellifera* L.? As is well known, the rule of priority begins as far back as the tenth edition of Linnæus' "Systema Naturæ," in 1758. In that year we find the honey-bee desigated by Linnæus as *Apis mellifera*. Three years later he named it *Apis mellifica*, probably because he recognized that the name first given was erroneous, for the bee does not carry in honey but nectar, making the honey in the hive. It is, therefore, not a carrier of honey (*mellifera*), but a maker of honey (*mellifica*). Be that as it may, the first author himself undertook the correction after a short time. Then developed an overwhelmingly rich literature concerning *Apis mellifica* (not *mellifera*), which is now inexhaustible, even to the specialists, if the non-scientific literature on bees be included. The bibliography of the late Mr. Edward Drory, of Berlin, relative to the honey-bee alone, embraces, for example, more than 2500 works. In the catalogue "Elenchus Librorum de Apium Cultura," Bibliographia Universale de Apicultura raccolta per Augusto Keller, 2300 works on *mellifica* are cited.

Under the circumstances Friese (as writer on Apidae for the Tierreich), and I have thought that, in spite of the rule of priority, we would not be justified in re-establishing the name "*mellifera*," which was recognized as incorrect, and shortly rejected by the first author. This is the result of mature deliberation at various times during many years. Not only were the reasons just mentioned arguments for retaining the name adopted 150 years ago, but also the knowledge that its establishment proves how powerless the regulations of the priority rule itself are in definite cases. They are powerless in spite of the rules for the "Tierreich," in spite of Della-Torre's "Catalogue Hymenopterorum," and even in spite of Friese and others of the originators of the priority rules for each case. For example, for the genus of solitary bees "Anthrophora," the name "Podalirius" was introduced, or at least according to the new system an attempt was made to introduce it. But here the case was like that of *mellifica*—the first author himself, for certain valid reasons, changed the name after a short time from "Podalirius" to "Anthrophora." Thus the name Podalirius did not prevail. It has not succeeded in becoming established in the lapse of years, and there is not the slightest probability that it will change in the future. I quote this discussion from my work which has just appeared, "Apistica. Beitrage zur Systematik Biologie, sowie zur geschichtlichen und geographischen Verbreitung der Honigbiene (*Apis mellifica* L.), ihrer Varietaten und der ubrigen Apis-Arten." Mitth. d. Kgl. Zoolog. Museums in Berlin, 1906.

of this there are the vague, defective assertions which are found in the newest editions of scientific works. Thus in a well-known text-book of zoology we read that a colony of bees contains about 10,000 workers. Such a small colony as that, 1 kilo of bees (5000 generally counted to a half-kilo) is not capable of developing under ordinary circumstances, nor of living over the winter. If a colony of medium strength is considered normal, then a normal colony contains at least 20,000 to 30,000 bees. The following statement also is wrong: "If a young queen emerges from her cell, then the former queen leaves the hive with part of the colony (first swarm) to found a new colony." Normally the swarm has issued by the time the cells containing young queens are sealed. Since it takes 16 or 17 days for the complete development of a queen, and the cell is closed on the ninth day, the hive is without an emerged queen for seven or eight days after the issue of the first swarm. The after-swarm, therefore, normally issues seldom before the ninth day after the issue of the first swarm. In Bechhold's Lexikon der Naturwissenschaften, 1894, there are similar incorrect statements. Among other things, a vigorous colony is said to contain, at most, 30,000 workers. But since strong colonies can sustain swarms of three or four kilos (27,000 to 36,000 bees), it follows that the whole number of inmates may amount to 60,000 or 75,000 and more, for usually a little more than half remain in the hive. Only 9000 swarming bees are counted to the kilo, because the honey-sacs of all are filled. Claus,[8] in a paper which contains many other errors, doubts that bees are able to hear. No zoologist who has done any experimental bee-keeping can have the least doubt that bees have an excellent sense of hearing, since observations yield him hundreds of proofs. The man who is not familiar with biological facts might recognize nothing of the kind with certainty, for up to the present the organ of hearing has not been discovered.

It appears, however, that the work of Otto Schenk indicates an advance in this direction (Schenk: Die antennalen Hautsinnes-organe einiger Lepidopteren und Hymenopteren, Zool. Jahrb., 1902). In this work on antennæ the presence of organs is demonstrated, which, with more probability than has been possible heretofore, may signify organs of hearing. Again, the work of Vitus Graber, "Die Insekten," München, 1879, in picturing the social life of insects, shows a series of errors and incorrect assertions so far as bees are concerned (Part II., 2d half, pp. 232-248). A refutation would take up too much space, and would lead me too far; but I might mention, for example, that Graber declares that the queen normally flies about inside the hive, because she "can not always pass *per pedes* through the vertical paths inside" (l. c., p. 88). Further, Wundt (Vorlesungen über die Menschen- und Tierseele, Leipsig, 1892), builds numerous far-reaching theories upon an incorrect biological basis. I shall speak of this in my "Conclusion" to this paper. The foregoing list of errors is not very complete, but let the matter end here.

While the founders[9] of our present knowledge in this sphere depended largely upon the results gained in practice, we see now and then an almost complete ignorance of the rich material which distinguished bee-keepers have laid down in the literature of practical bee-keeping.[10]

As to terminology, I shall not use Bethe's phrase, "psychic qualities" (Psychische Qualitaten), since it can be interpreted in various ways. Bethe gives it a definite significance,

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[8] Claus, Der Bienenstaat. Part 179 of the collection of scientific papers published by Virchow und Holtzendorf. Hamburg, 1873.

[9] Francois Huber, Nouvelles Observations sur les Abeilles. Geneva, 1814; German by G. Kleine, Einbeck, 1856; English editions in 1823 and 1841. This investigator, blind since his twentieth year, could not have carried on his observations without the help of his unusually efficient bee-keeper Burnens.

v. Siebold Wahre Parthenogenesis bei Schmetterlingen und Bienen, Leipzig, 1856, etc.

Leuckart, Zur Kenntnis des Generationswechsels und der Parthenogenesis bei Insekten, 1858, etc. Surely the histological findings of these last-named investigators with regard to the presence of spermatozoa in bee eggs can no longer be esteemed as free from objections. They doubtless depend upon an illusion, for, as I have shown before (Der Befruchtungsvorgange im Bienenei, Bienenw. Centralblatt Nr. 16, v. 15 August, 1899; further in Aus den Wundern des Bienenstaates, ibid, 1900), according to my investigations, the spermatozoa undergo the transformation into sperm nuclei in about 15 to 20 minutes (cf. Weismann, Vortrage uber Deszendenz Theorie, II. Aufl., 1904, p. 250, I. Bd.); while v. Siebold says he has seen living spermatozoa in eggs after 12, 15, and 22 hours. I believe, therefore, that in Blochmann's paper (Ueber die Zahl der Richtungskorper bei befruchteten und unbefruchteten Bieneneiern, Morphol, Jahrb., 15 Bd., p. 85-96, 1889), and in Paulcke's investigations (Zur Frage der parthenog. Entstehung der Drohnen (Apis mellif.), XVI Bd., pp. 474-476, Anat. Anzeiger v. 5 October, Jena, 1899, Vorlaufige Mitteilung), we have the first safe histological corroborations of the theory of parthenogenesis in the honey-bee. In the meantime Petrunkewitsch has given full confirmation (cf. Petrunkewitsch, Alex., Natural and Artificial Parthenogenesis, Amer. Naturalist, Vol. 39, 1905).

[10] v. Siebold (l. c., p. 57) expressly refers to the findings of bee-keepers as "the most important work."

comprehending under it everything acquired in the life of an individual, and also every capacity for sensation and learning; in short, everything that transcends unperceived reflex activity.[11] He considers ants and bees as mere reflex machines: "It seems to me that these insects have no senses, have no ability to make experiences and modify by it their actions; that all stimuli remain below the threshold of perceptible sensations and perceptions, and that they execute, in a purely mechanical way, all the apparently reasoned actions" (Bethe, l. c., p. 98). Whether this view is warranted, we shall see further on.

The terms "reflex" and "instinct," I shall use in the significance Bethe gives to the word "reflex." Instinct is complicated reflex.[12] He lets pass as reflex the inherent faculties; the course of nervous processes is determined by inherited instincts. That acquired in the life of the individual shows the opposite; here the course of the nervous processes indicates experience, memory, learning, capability for association, etc.[13] I shall restrict myself here to these short statements, but shall add some psychological views in the concluding chapter.

I shall first discuss the "Hive Odor" and reactions resulting from it, then give my experiments and opinions on the capacity for intelligence in bees, and end with my conclusions concerning the homing instinct in bees, or the ability to find the hive, etc.

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[11] Bethe drops this expression in "Beer, Bethe, und J. v. Uexkull, Vorschlage zu einer objectivirenden Nomenklatur. Biol. Centralbl., 19 Bd., 1899, Nr. 15, p. 517 (also in Centralblatt fur Physiologie, 1899, Nr. 6); and further in Bethe's "Noch einmal uber die psychischen Qualitaten der Ameisen," Archiv. f. d. ges. Physiologie, Bd. 79, 1900, p. 45.

[12] H. E. Ziegler, Ueber den Begriff des Instinkts. Verhandl. d. deutsch. zoolog. Gesellsch., 1892.

[13] H. E. Ziegler, Theoretisches zur Tierpsychologie und vergleichenden Neurophysiologie. Biol. Centralbl., Bd. XX., Nr. 1, 1900.

THE HIVE ODOR AND THE REACTIONS RESULTING FROM IT.

In the first section of "Investigations on Bees," Bethe (l. c.) treats the question as to how bees recognize the hive, and concludes that the recognition results solely from an odorous chemical compound (Geruchsstoff) which he calls the "hive substance" (Neststoff).[14] He avoids the term "hive odor," because he thinks bees have no sense of smell. I use the expressive term "hive odor" (colony odor, exhalation odor) under which I comprehend only the existence of gaseous substances disseminated in a colony, the presence of which is detected by the bees' sense of smell.

I believe that the following odors are present in a colony of bees:

1. The Individual odor. It can be easily demonstrated that the queen odor (see p. 7) varies with different individuals, and on the same ground (germinal variation), an individual odor should be assigned to the workers.

2. All offspring of one mother (queen) have a common inherited family odor in addition to the individual odors, belonging only to the progeny of one queen.

3. The brood and chyle odor (p. 9).

4. The drone odor (p. 10).

5. The wax odor. Since the wax is a granular secretion, an exuded product, it may be safely taken for granted that, considered apart from the specific odor of wax, the individual odors of the wax-generators adhere to the honey-comb. Accordingly the wax structures of different colonies have different odors.

6. The honey odor. That the honey of each colony (mixed with a secretion of the salivary glands) has its specific odor is readily seen from the old practice of bee-keepers to which Bethe also alludes. If a queen be daubed with honey from a queenless colony, she will be accepted readily by that colony when inserted.

7. The hive odor (exhalation odor, colony odor). The hive odor is composed normally by a mixture of the preceding odors, or of some of them. Single bees, therefore, besides their individual odors, possess the family odor and especially the common adhering hive odor, which forms the dominant factor in the various actions toward hive mates and hive strangers—that is, in mutual recognition between bees.

If a strange queen is put into a queenless colony in a cage, a confinement of twenty-four hours is usually sufficient for the queen to have received the "hive substance," as Bethe calls it; that is, she has become "scented."[15] The external adherence of the colony odor therefore suffices to make the bees permanently friendly with the foreign queen. If a swarm is made of the bees hanging in front of several hives,[16] which in strong colonies often form great clusters (beards), by scooping them up in a ladle, there will probably be bees from ten, twenty, or thirty different hives. If they are put into a hive and given a queen, with the observance of proper precautions, these bees from, let us say, thirty different hives, form a peaceful colony in a few hours, which adjusts itself in its new dwelling and takes up the ordinary tasks of the day. Here we have thirty family odors, and about

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[14] According to Bethe we must consider the existence of this "hive substance" as a "family odor." "I believe that these family odors, common to all the members of one family, and differing slightly from those of other families of the same species, play an important part in the life-history of the social hymenoptera. This family difference is due to the varying proportions of the constituent odors" (l. c., p. 31). This "hive substance" must be inherited, as Jager likewise maintains (Zeitschrift fur wissensch. Zoologie, Bd. 27, 1876, p. 327). I might mention here that I find no proof in Jager's paper that he concludes the "exhalation odor" of a colony to be solely a "family odor" as Bethe does, and still less proof that he considers this common odor to be "inherited," because it is a mixture of many thousands of inherited individual odors.

Bethe includes, under the term "hive substance," two separate substances, one giving the family odor and the other causing the "various reactions toward hive mates and hive strangers." That this conception will not cover all cases, I believe I can demonstrate in the course of my paper.

[15] Further on I shall show that in many cases the bees very likely became familiar with the odor of the queen, which is a mixture of the queen odor and the hive odor.

[16] G. Dathe, Lehrbuch der Bienenzucht, 5 Aufl., Bensheim, 1892; Bienenzeitung, 7 Jahrg., No. 19.

thirty to forty thousand individual odors united into a special hive odor, peculiar to this colony alone, merely by the scooping together. The proof of this can be found in the fact that a queen placed in such a colony can be set free frequently after only twelve to twenty-four hours; she has taken up the hive odor.

We see, therefore, in this case, a colony without a specific family odor conducting itself exactly like colonies which are made up of the offspring of one mother. In each case the hive odor is formed by the union and mixing of individual odors.

Now the question arises: Is this hive odor inherited? No, surely not, for the hive odor, therefore the common odor, that each individual can take up in an external way is something purely exogenous or acquired.

The power of the hive odor seems to me, therefore, to lie not in the inherent family odor nor in the inherited individual odors, but in the exogenous mixture of the two. What Bethe (l. c., p. 43) alleges for compound nests (Schüttelnester), and communicates in his experiments on bees (p. 71), is not a contradiction of this. He says that bees that had been transferred to another hive did attack almost not at all or with only slight enmity their sisters remaining in the mother hive because the common family odor lessened the hostile reaction. This proves merely that the hive odor differs from the family odor. If the latter were the predominant factor, bees of the same family would always be friendly with each other, which is not the case.

Further, I can not regard this, the only experiment which Bethe employed (l. c., p. 71), as conclusive, since very many circumstances which have nothing to do with the hive odor affect the friendly or hostile attitude of bees, be they sisters or strangers. The forage, weather, time of year, strength of the colonies, quantity of provisions, etc., all have an influence, as is well known to those who have studied the peculiarities of bees for many years. In my experience, estrangement seems to take place between separated hive mates generally much more quickly than Bethe states, yet I think this is on the whole a secondary matter which does not touch upon the principal point.

MODIFICATION OF REACTIONS TOWARD THE HIVE ODOR.

It is contested by Bethe that the "various reactions" are based upon hive-mate and hive-stranger modifications.[17] It seems to me that it is hardly possible to grant such a far-reaching conclusion when Bethe's investigations give no striking proof that reactions toward the hive odor are incapable of modification. We learn nothing from the illustration given above. In the critical examination of robbing between colonies, we find that a great number of factors enter, which can be discovered only after years of keen observation and fortunate circumstances. In the manual of bee instruction which I helped to publish [18] (see p. 9), I recommended also fumigation of the hive of the robbing and not of the robbed colony, but that is no proof that the hive stimulus can not be modified. Bethe believes that no psychic elements enter into the actions of a colony and apparently the short time he could devote to bees led him to this view. I submit the following investigations on this question.

THE SWARMING-OUT OF A QUEENLESS COLONY.

If two hives are placed close together, and the queen and brood are removed from one, it sometimes happens that the entire colony, from which every possibility of rearing a queen has been removed, will enter the queen-right [19] (weiselrichtigen) colony, humming

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[17] "It has been thought possible to make the individuals of a hive 'recognize' each other better by fumigating the colony with some strong-smelling substance—Camphor, naphthaline, baldrian, for instance. If this be done to a colony exposed to frequent plundering it is thought that the bees of this hive will more readily detect the robbers to whom the scent does not adhere. Were this correct, then it would prove that the various reactions toward hive mates and hive strangers could be artificially modified.

"I believe that I can assert positively that such treatment does not increase the reaction toward strange bees in the least, but only that the bees of all strange colonies react more vigorously toward the individuals thus scented. (Therefore if it is desired to defend a colony from robbing, it is the robbing and not the robbed which must be fumigated.)

"We see, therefore, that here, as in ants, the various reactions toward hive mates and strangers bring us back to a simple chemical reflex" (Bethe, l. c., p. 71).

[18] G. Dathe, Lehrbuch der Bienenzucht, 5 Aufl., published by R. Dathe and H. Keepen (v. Buttel-Reepen), Bensheim, 1892, p. 181.

[19] There is no word in common use among English-speaking bee-keepers to indicate the normal condition of a colony in the possession of a queen, either mated or unmated. It seems desirable, therefore, to translate the German term literally, although "queen-right" is an undesirable term. It has already been used by some American writers.—E. F. P.

"joyfully." These bees seldom sting, and are received in a friendly manner, although the normal queen-right colony should react hostilely, if it followed a chemical reflex incapable of modification. What causes this swarming-out of the queenless colony we shall see further on.

INTENSIFYING THE REACTION.

If a colony tolerates robbing without attempting to suppress it, a stimulating food should be given it, such as fermenting buckwheat honey[20] several years old or a mixture of honey and brandy, and the hive should be shaken to arouse the anger of the bees, etc. Then a better defense is made, the irritability of the colony is increased, and robbers are better recognized and repulsed.

The "courage" and the "attention" of the colony are increased, and therefore we have intensified reactions toward hive strangers.[21]

OVERCOMING THE REACTIONS TOWARD HIVE ODOR.

It is interesting that this powerful reaction toward hive odor, though generally acting hostilely, can be subdued and turned in other directions. Thus bees which blunder into the wrong hive, as they return from the fields with filled honey-sacs, are seldom attacked.

The behavior of such "begging" bees is most peculiar. With the abdomen dragging on the flight-board, the proboscis far extended and dealing out the honey to her tormenters, she is trying to insinuate herself into the hive in order to deposit her honey, and in this she often succeeds. (Here and further on I use anthropomorphic terms for better demonstration. It is understood that many of these actions rest upon reflexes and instincts, but it makes the case clearer to use such terms, as "to insinuate" for example.)

The old practice of transposing hives is based on the fact that strange bees, laden with honey, are received in a friendly way. If a weak colony needs improving, it may simply be put in the place of a very strong one, the two hives changing places. This transfer will be successful only on days in which there is a good honey-flow and all flying bees return heavily laden. If the hives have the same outward appearance, and (most important) have their entrances at the same height, almost all bees will fly in as usual. Thus the weak colony will be strengthened from the strong one, and stinging seldom occurs.

Also, if one wishes to prevent swarming, the flying bees may be drawn off in the same way. I can not at this point go into the many modifications of this practice, and must refer to the manuals of instruction.

If a strong colony stands next to a weak one during a rich honey-flow, and succeeds in filling its own chamber to overflowing, it happens now and then that the strong colony, having no further room, will help to fill the hive of the weak one in the most peaceful way. So we see that of two colonies which should react hostilely toward each other, either one or both may be put under peculiar conditions in order to handle both in the same way with a peaceful reaction between them. For example, if two colonies are sprinkled with some strong-smelling liquid, or powdered with meal, they may be united without risk.

If bees are stupefied with saltpeter, chloroform, ether, or puff-ball, the same thing can be done with no danger of mutual stinging, but at the same time the earlier orientation is completely lost. When the bees recover from their stupor they no longer recognize their own colony, and can be united to other colonies at will. What conclusions are to be drawn from this capacity for learning, etc., we shall see later on.

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[20] Dathe, l. c., p. 179.

[21] The Luneburger bee-keepers sometimes employ a particular method for putting a stop to robbing. If the honey-flow is strong, so that the powerful odor of honey issues from the hive-entrance, a general robbing occasionally goes on; but the robbers are hardly noticed by the bees of the hive, apparently the strong odor of honey covering the strange odor of the robbers, or the certain, quiet entrance deceiving the inmates of the robbed colony. In order to call out a stronger reaction, the bee-keepers turn over the skeps so that the wider opening of the skep is turned to the front. One would think that, since the whole honey-comb is now open to the air, robbing could be effected more easily; but this is not the case, for the powerful odor of honey is now easily "dissipated," and the robbers, because of the change in the position of the entrance, are uncertain, and hesitate. Thus the attention of the colony is drawn to the robbing, the fortification is well protected, and every attack is beaten off (cf. G. Lehzen, Hauptstucke der Luneburger Bienenzucht, 1900, Hannover).

Incidentally, I might mention here a curious aberration of instinct. The literature of bee economics records some cases in which bees showed unaccountable hostile reaction toward their own hive mates. Thus it has been observed sometimes that a colony will sting a great number of its own flying bees as if they were intruders. This behavior has been noticed for a long time, and it finally did lead to the destruction of the colony. Possibly here there is a degeneration of that instinct which causes colonies to place bees at the entrance to control the flying in. Perhaps differences of odor come into account, or perhaps both stimuli act together.

It is probable, too, that we may be dealing with defective observations, although errors of instinct in bees are not at all uncommon, and frequently in the spring it can be proven that bees, in an inexplicable mistake, even attack their own queen and ball her. The colony is then in wild confusion, and between the combs or on the bottom-board is the poor queen in the middle of a cluster of bees; she often comes out of the tumult a cripple. Another case of failure in instinct is as follows: As is well known, bees now and then build queen-cells over drone eggs.[22] If a queen-cell is of more than ordinary length it is tolerably sure to contain a drone larva.[23] The too invigorating royal jelly[24] seems to be unwholesome for the larva; it falls out from the food because of the abnormal size of the cell, and that is the cause of their always lengthening the cell. Usually the drone dies.

THE ODOR OF THE QUEEN.

The individual odor of the queen is doubtless in many cases a very small part of the odor of the hive, but often may form the dominant factor. The exhalation of the queen is so intense that it can be perceived by man. It is very characteristic and adherent, being somewhat like the odor of thyme. If a queen is crushed on a board, the bees of her colony smell for several days around the place where she was killed. If the bees are allowed to run over the board, they gather there; and, lifting the abdomens, fan their wings in a peculiar way.

It often happens that after-swarms, also swarms with young queens, fly together and unite into a powerful swarm-cluster. The bees in this cluster do not attack each other, in spite of the varied hive odors. The "swarm-dizziness" extinguishes the reactions toward the foreign hive odor, just as it also almost destroys the sense of orientation, so that the impulse to seek the parent colony is lost,[25] at least under normal circumstances. The swarming bees, instead, remain in the home they have taken up; the field bees, which some days before, or immediately before the swarming, have been bringing honey, pollen, and water to the parent colony in the usual way, will, a few hours later, after they have become oriented, bring their burdens into the new hive. Under the proper conditions this can be placed adjoining the old one. The memory of the old birthplace has completely disappeared. I shall speak later on of an exception to this.

If it be wished to separate these united swarms, the whole cluster may be put into a large box containing as many twigs of a tree as there are swarms. Over night the colonies separate of themselves, each hanging on a twig.

It is safe to take for granted that a purely mechanical separation takes place here, and, evidently, according to the various hive odors. I nevertheless believe that a still more powerfully determinative stimulus enters—the odor of the queen. Each colony congregates around its queen;[26] and if the queen is taken away from one swarm it will unite with another possessing a queen, in spite of the hostile hive odor.

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[22] O. von Roth, Ueber abnorme Zustande im Bienenvolk. Berichte der Naturf. Ges. Freiburg i. Br., 8 Bd., 1894.

[23] There is also a prevalent idea that such cells are not as rough as normal cells containing queens; some books on bee-keeping even go so far as to try to figure the difference.—E. F. P.

[24] Concerning the varied chemical composition of pabulum for the three kinds of bees, see A. von Planta. "Uber den Futtersaft der Bienen," and "Nochmals uber den Futtersaft der Bienen," Schweiz. Bienenzeitung, 1888-'9; further, A. von Planta, Zeitschrift f. phy. Chemie von Hoppe-Seyler, 1888, Bd. 12, Heft 4, pp. 327-354, and also Bd. 13, Heft 6, pp. 552-561; further, Dathe l. c., p. 24.

[25] Bethe, in dealing with the "psychical qualities," has not considered either the act of swarming, which is an all-important factor, or the individual odor of the queen. We shall see presently what interesting bearings swarming has on this question.

[26] Some may take exception to this statement, perhaps, and believe that this gathering together is due to other instincts—the sex instinct or the instinct to swarm which is characteristic of bees; but it must be kept in mind that the bees separate into single colonies only if the queens of the various colonies are present, manifesting their presence by the scent which exhales from them.

It may be thought that here the family odor, the possession of all the offspring of one mother, enters its claim; but I notice that the swarms may be united ingeniously, even if the queen does not originally belong to the colony in question, but comes from a queen-cell taken from a strange colony. In addition, we continually have to do with unfertilized queens in normal after-swarms, therefore we can not speak of the offspring of one mother at all. The queen of an after-swarm is the sister of the workers, if I may so express myself.

It is the queen odor familiar to the bees which acts with the hive odor (to be sure, the reaction toward the latter seems to disappear during the swarming), and perhaps holds the community together, but the queen odor is the dominant factor. This may be seen from the first experiment (p. 5) also, to which I shall now return. The bees of the queenless colony scent the queen in the neighborhood hive, and, paying no attention to the foreign hive odor (toward which, under ordinary circumstances, they would react sharply), they go over into the enemy's camp "humming joyfully." Very probably sound perceptions also come into consideration—that is, the reaction toward the humming of the "queen-right" colony (see later).[27]

If the odor of the queen is so powerful, it is clear that this individual odor alone determines the special character of the hive substance, especially when this is particularly strong. This would happen in the spring during the increased sexual activity[28] which is demonstrated by the enormous number of eggs laid (2000 to 3500 and more in twenty-four hours). That it is not always the determining factor, follows from the fact that there remains a hive substance capable of causing reaction, even if the queen is taken out and kept at a distance.

At such a season, during the strongest breeding period, the bees care for the queen with special zeal. It may not be the very "sympathetic" odor[29] alone which causes them at this time to surround her in a close cluster, for her increased need of nourishment[30] increases the constant care of the bees around her. Nevertheless, the singular pleasure that bees take in the strong mint-like exhalation from the queen is shown in the attachment of the "court," this affection being demonstrated by the single "courtiers," who from time to time lick the abdomen or thorax most zealously, humming continually in a characteristic "contented" way.[31]

The bees wish to sniff the odor, so to speak. A queen in an observation have can be seen constantly surrounded by a circle of brood nurses who continually turn the head to her. If she advances slowly, the bees yield the way, moving backward. From time to time the "caressing," licking, and feeding go on. It can be easily understood how this attitude has often been interpreted as the expression of a peculiar reverence toward the "ruler of the community." The "respectful" walking backward, the "tender" licking, the irreproachable service (as the queen never leaves the hive, she is forced to deposit her fæces in the hive, and the "courtiers" immediately clean away all traces) closely approach anthropomorphic appearances. But perhaps it might be proven that the individuality of the queen is the dominant factor. A foreign queen with the same strong odor of mint would be stung in spite of the pleasure in the smell.

In autumn and winter, also early in the spring, the bees concern themselves relatively very little with the queen, and still less with a young virgin. The lessened exhalation (it is as yet very weak) may explain this phenomenon in part.

It seems to me that if the odor of the queen is extremely penetrating and adherent,[32]

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[27] In this there might be found an apparent contradiction to the "disregard of the queen" p. 14). The finding of the queen in the next hive is not by scenting from hive to hive, for the distance is too great. The agitated queenless bees run searching over the front wall of their hive and also over the front wall of the one standing next. In this way some come to the entrance of the neighboring hive, where the odor of the queen and the sound of contented humming are issuing forth. At once they begin to lift the abdomens, and fan with their wings. Their mates near by take up the humming, and soon the whole colony enters the queen-right hive in order, with lifted abdomens and fanning wings.

[28] Jaeger, Ueber die Bedeutung des Geschmacks- und Geruchsstoffes. Zeitschrift f. wissensch. Zoologie, Bd. 27, p. 327, 1876.

[29] In order to keep a swarm in the hive, the hive may be rubbed with thyme.

[30] As is well known, the queen can eat only honey independently; but the probosces of the workers are necessary to feed her with nitrogenous food.

[31] I might say again that anthropomorphic designations are chosen for purposes of clearer demonstration.

[32] I took the queen from a strong colony, put her in a cage, and after a few minutes removed her. Fifteen minutes later I placed the empty cage upon the flightboard of the colony concerned. Immediately the bees scented the odor, and alighted, fluttering upon the cage, which they had completely ignored before (see also p. 7).

as it doubtless is, the view (mentioned also by Bethe) that the queen takes on the hive odor of the queenless colony in which she is placed in a cage, is not correct in all cases, for the colony is "scented" by the strong odor of the queen, which is distinctly perceptible to our sense of smell. Very rightly, therefore, O. von Rath[33] says that "the workers first accustom themselves to the odor of the queen." The stronger, then, the exhalation from the queen, the more easily must be her acceptance, or scenting of the colony proceed; and consequently the mutual friendliness also. I find from many investigations that a mated queen heavily laden with eggs is more easily accepted than an unfertilized one. The following rules[34] of bee-keeping harmonize with this statement: 1. "An unfertilized queen is not accepted by many colonies if formerly they have had a fertilized one." 2. "The older a queen is, the more readily is she accepted." 3. "Weak colonies accept queens more easily than strong ones." 4. "Queens of the same kind are accepted with less difficulty than those of different varieties; as for example, Italians, Caucasians, Cyprians, etc." Here in every case the different odor of each variety plays its part.

It may seem obvious that it is easier to demonstrate this scenting, whether it be on only one side or mutual, with a weak colony, but here other instincts come into consideration too, as we shall see further on.

THE BROOD ODOR.

It is highly probable that it is not only the odor of the queen at all times which causes a queenless colony to enter a hostile camp (see p. 5), but during the months of greatest increase, from March to June or July, a powerful constituent of the hive odor is the odor of the brood, a warm characteristic vapor exhaling from the thousands of brood-cells. The chemical processes going on at this time in the cells for the development of the larvæ are of so intense a nature that a temperature of 28 to 32° C. is maintained in the brood-chamber. On spring days this exhalation from the brood, which smells like freshly baked bread, may be perceived some distance away in the direction of the wind. Very probably this strong odor sets free the same reaction in queenless and broodless colonies as the queen odor does; but as such colonies always go over to the queen-right colony, even if there is no brood at all or only a minimum amount, so in spite of this vapor from brood and pabulum (the larvæ swim in food), it is very likely the queen odor and the humming of the queen-right colony which are of first importance.[35]

But, on the other hand, the attachment of the bees to the brood is very strong, as may be seen from the fact that an unruly swarm, which has already withdrawn from one unaccepted hive, will certainly remain if a frame of brood is hung in it. Again, swarms can often be enticed from an undesirable place for capturing them (the middle of a hedge, for example), by means of a frame of brood.[36]

THE INDIFFERENT ODOR OF YOUNG BEES.

Young bees, particularly those just emerging, have an apparently faint and indifferent odor, and they are, therefore, not attacked in a strange colony; the same thing is true of young queens. In cutting out queen-cells, it happens repeatedly that the young queens which are entirely or nearly "ripe" free themselves from their compartments. If such a queen is immediately allowed to run through the entrance of a queenless colony, the queening is usually successful. This depends, perhaps, upon the fact that, as described, the individual odor is not yet developed, analogous to the similar indifferent "infant odor," and that the common reaction-loosing hive odor has adhered but little so far. It is curious that there are colonies which will not allow themselves to be requeened;[37] then all artifices are in vain.

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[33] O. von Roth, Ueber abnorme Zustande im Bienenvolk, Berichte der Naturf. Ges. Freiburg i. Br., 8. Bd., 1894.

[34] Dathe, l. c., p. 211.

[35] The "constancy" of bees to their queen, which is always the dominant instinct, manifests itself in a starving colony by the fact that the queen is always the last to die; she is fed to the end by the dying bees. In order to confirm this, I put a queen with a few bees and very little food into a box covered with wire gauze. After forty-eight hours the bees were very weak; two days later only four were still alive; the next day but one was living, while the queen was apparently as vigorous as ever. The last surviving worker lay on its side unable to crawl; but when the hungry queen approached demanding food, it tried feebly to join its proboscis to that of the queen in a vain attempt to give her food. Finally the queen turned away; and when I looked again, half an hour later, the last worker was dead, but the queen showed no sign of weakness. I then put her back in the colony.

[36] Dathe, l. c., p. 225 and 230.

[37] Bienenwirtsch. Centralblatt, Jahrg. 28, Heft 19, p. 298, 1892.

However, in the winter months, when the bodily functions which determine the intensity of the individual odor are for the most part quiet or weakened, the strength of the individual odor decreases. In consequence of this we have prompt friendliness with strangers, since the lessened odor of the hive excites only a weak reaction. Therefore a union of colonies can be undertaken in early spring without observing the precautions otherwise necessary.

I noticed one day a change in two hives standing close to each other, which was totally unintelligible to me. Colony "A," in which a vigorous increase was to be expected, showed a constant diminishing of numbers, while colony "B" strengthened in a surprisingly short time. By good fortune colony "A" was of the native brown variety, and colony "B," a yellow Italian hybrid. This color distinction of the varieties, which has helped to solve so many mysteries of the domestic economy of bees, brought the explanation in this case. I was soon sure that colony "B" was taking up the young from the other hive, and I found out how after long observation. A passage through possible crevices could not take place, nor could the crossing be from one alighting-board to the other; therefore only the flying bees had to be taken into consideration. I noticed after some time that the young Italian bees always took their flight of orientation earlier than their neighbors. Now, when a thick cloud of these young bees, humming loudly, would be flying in front of colony "B," the native colony would gradually begin to send out bees for orientation, but its mass of humming bees was always considerably smaller. This was because many bees, attracted by the loud buzzing, immediately plunged into the neighboring tumult, there oriented themselves, and accordingly entered colony "B" thereafter. There they were accepted on account of their indifferent odor, and chiefly, perhaps, because of their entirely "harmless" conduct.

FAILURE OF THE HIVE-ODOR REACTIONS IN QUEENS AND DRONES.

It is of interest that the hive odor of a strange colony causes no reaction at all in a queen. Queens never react either peacefully or hostilely toward strangers or toward bees belonging to the hive. They demand nourishment from every bee, and they maintain themselves even in the most hostile colony as long as it is queenless. Even the "angrily buzzing" bees which besiege the queen-cage in a solid mass, and which try to bite and sting the queen through the wire cloth, put the required food into the extended proboscis of the queen. In this manner a queenless colony will often feed ten or twenty confined queens; but if one should accidentally free herself and be accepted by the colony, then the bees will let the rest starve.

The queen recognizes as an enemy only her "rival," even if reared in the same colony (daughter or sister), and who, therefore, must have the same family or hive odor. If two queens come upon each other, only one will remain on the battlefield.[38]

If the queen is pleasing to every bee in every colony, the same thing may be said of the drones, who are extremely cosmopolitan, and who loaf about from hive to hive, and in consequence, apparently, of their specific odor, they are received peacefully everywhere, provided, of course, that the killing of the drones has not yet begun. At no time do they display the smallest response of any kind toward other bees, except when they accomplish the object of their existence in the mating-flight.

ABNORMAL HIVE ODOR.

It is worthy of note that drone-producing (fertile worker) colonies, that is, colonies in which the workers take to egg-laying because a queen is lacking, and on account of

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[38] The queen is normally the absolute "monarch" in the colony; but in spite of that we not seldom find cases where there are two egg-laying queens. Here we have the successor encroaching upon the old decrepit queen before the latter dies. But under such circumstances there are always two brood-nests—the queens do not come together. The following observation stands alone, and is the more remarkable because it has to do, not only with two queens, but with two of different varieties. "Since I had the opportunity," writes one Mr. Breuer, in the Rheinischen Bienenzeitung, "to obtain a purely mated Carniolan queen, I took out the old queen on July 17th, and put in the Carniolan. She was accepted without delay and immediately began laying. Another queen was positively not present in the colony. The brood developed quickly, but I kept noticing among the young bees Germans as well as Carniolans. When I revisited the hive I found upon the same frame, hardly five centimeters apart, two magnificent queens, peacefully together—one German, the other Carniolan. The brood-nest was not divided, but just as normal as if the eggs had all been laid by one queen." (See reference in Bienenw. Centralblatt, No. 22, 1899. Hannover.)

lack of brood, are not only difficult to requeen, but also equally difficult to unite with queen-right colonies. This is doubtless in consequence of the peculiar hive odor called forth by the presence of so many egg-layers whose number increases the longer this abnormal condition lasts. According to the investigations of Dohnhoff, almost all the bees finally lay eggs without conducting themselves differently from the usual non-laying bees.[39] A true queen odor does not seem to develop, and I have observed that drone-laying queens are never rendered the "homage" which a normal queen receives. As long as she is unfertilized, she seems to be unnoticed by the inmates of the hive; but as soon as she begins laying eggs she has around her constantly a ring of "courtiers" (see p. 7). Other colonies very frequently may be united without special precautionary measures, but not so with fertile-worker colonies, which can be joined successfully only by the application of very special precautions.[40] We therefore have here an abnormal hive odor of a peculiar kind.[41]

In any case it is evident from the foregoing that the hive odor is exceedingly complicated—much more so than would appear from Bethe's account; and the idea of a simple chemical substance and a chemical reflect, incapable of modification, is not enough to clear up the proceedings which are involved.

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[39] Bienenzeitung, XIII. Jahrg., No. 20. In passing, I might submit the following: It has been shown experimentally that, as in the circumstances cited, the workers (normally sterile) take up egg-laying. I shall here mention only one such investigation, and shall not take up the various anthropomorphic explanations which are usually given. There is a wide-spread view among bee-keepers that the larvæ of workers which are located nearest to the queen-cell are fed occasionally on royal jelly by mistake; on account of this exceptional nourishment, it is believed that a better development of the ovaries may take place. This view is held also by v. Siebold and Huber. (The ovaries of workers normally consist of about twenty to thirty egg-tubes, whereas those of the queen contain about four hundred. Parallel with and partly qualified by this view is the incorrect idea that there is only one or a few egg-laying bees in a drone-producing colony; but if one realizes that almost all workers in such a colony lay eggs, this view is already weakened. In my opinion we here have to do with the same reflexes which induce a colony to produce a young queen during the lifetime of an old weakened queen that is laying eggs in insufficient numbers. What "prudence" and "deliberation" on the part of the bees this suggests to the ordinary observer! Again the same reflexes impel a colony to erect queen-cells if the queen is kept confined for a long time (see p. 14.) It is, I believe, for the greater part an unsatisfied instinct for feeding. In the first case we have the pabulum, which is produced in great quantity, and which is not reaching its natural destiny, acting to produce a hypernutrition of the bees, and consequently the stimulation of organs which normally are not stimulated at all.

[40] Dathe, l. c., p. 161.

[41] I shall not consider further the special abnormal hive odors generated by disease (dysentery, foul brood, etc.), nor through the irritability over the lack of the queen.

THE MEANS OF COMMUNICATION IN BEES

According to Bethe, there is not "the slightest doubt" that bees recognize each other or hive strangers only by odor (chemical substance), and that no special means, neither a "sound" nor a "definite movement of the antennæ," comes into question as possibilities for communication.[42]

Long-continued and careful observations, however, yield many data which do not coincide with this view.

INVESTIGATIONS WITH COLONIES FROM WHICH THE QUEENS ARE TAKEN.

If the queen is taken from a very strong colony of 50,000 to 60,000 bees or more, the loss is first noticed sometimes after an hour, sometimes after many hours. This is particularly the case if the removal is made during a rich honey-flow when the bees are busily occupied with bringing in and storing the nectar. A striking change then suddenly takes place, the comfortable humming gives way to a louder, long-drawn-out, lamenting buzz.[43] The guards at the entrance and those providing the ventilation become uneasy; excited bees come out of the hive and run over it as if seeking something; single bees fly away quickly, then back; the whole character of the colony is changed—not only in outward behavior but also in inner disposition. They are very irritable, and inclined to sting. I have sometimes noticed the queenlessness of colonies, which usually were very gentle, by the increased desire to sting. Such notice is, of course, possible only to one who is used to working without veil or gloves.

If the door[44] of a queenless colony is opened, the same agitation is seen in the interior, and smoke blown in only increases the buzzing. This excitement over the loss of a queen often appears very soon after her removal, particularly when there is no forage or if the colony is weak.

The difficult question now arises, how bees notice the absence of the queen and how they communicate this loss. Is it the sudden absence of her odor? Hardly, at least not in all cases, for we have seen in a previous paragraph that the odor of the queen is exceedingly adherent, and therefore the walls, as well as the bees, must be impregnated with it. But the intensity is gradually becoming less. However, this odor is variable in the customary course of events,[45] and so no uneasiness of any kind arises on this account. Furthermore, how does it happen that the bees *suddenly* become agitated after the queen has been taken out sometimes for an hour or more?

If Bethe is right, that the means of communication depend upon the outflow of some chemical, then the above observations would prove at least that the odor of the queen is a very dominant one in the colony. The queen then does not, as Bethe declares, take on the hive substance, but just the opposite happens; the queen influences the hive odor considerably, or at least a mutual scenting takes place. On the other hand, if we agree with Bethe in his statement that the queen takes up the hive substance of the colony, the means of communication must depend, not upon reflexes of smell alone, because the colony odor would not be influenced by the removal of the queen.

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[42] Bethe, l. c., p. 70.

[43] That "agitated bees" constantly "buzz" is a misleading expression of Bethe's. Particularly can the humming with raised abdomens and fanning wings upon the flight-board be sharply distinguished by the trained ear from what is usually called the "buzzing" of bees, by the pitch.

[44] Reference is here made to the German style of hive with a door in the rear. The American style of hive opening at the top is little used in that country.—E. F. P.

[45] If the queen gets into the honey-chamber, which is generally separated from the brood-chamber beneath by a strong piece of board with slits in for the passage of workers, and if she there continues to lay eggs, it is clear that her odor must soon be lost to the bees beneath. This is especially true if there is an entrance into the honey-chamber. Under these circumstances, however, excitement at the queen's absence never breaks out; at most the "isolated" bees after a few days occasionally build queen-cells, but more often not.

If we were to ask bee-keepers their opinion in this matter, they would probably answer that the young bees which care for the feeding of the brood and the queen "miss" the latter after a longer or shorter period, and begin to seek her diligently, communicating their anxiety to the whole colony until the "conviction" that the queen is gone comes into consciousness, when the comfortable humming changes to a loud buzz.

But since the young bees, as all bee-keepers know, can be taken away very well with the queen it naturally follows that they take no very important part in this matter. Then the old bees will begin the loud buzzing.

One can, however, ingeniously gather a colony of old workers and place within it a queen enclosed in a cage. The excited colony is quieted as if by magic. The hostile bees next to the cage begin to list their abdomens, fanning their wings,[46] with a characteristic humming. This hum is taken up by other bees, and suddenly there is a peaceful quiet.

Before we formulate conclusions from the foregoing let me communicate further observations.

The following experience is interesting, and proves that the feeding of the queen as one of the chief phenomena of life needs not to be taken into consideration in the breaking-out of the agitation over the loss of a queen, apart from the odor.

In bringing in a first swarm, I crushed the queen by accident. Since I could not care for it on that day nor the next, and I did not have another queen at my disposal to substitute, I knew that the swarm would certainly fly out again and join the mother colony. To prevent this, I arranged the following experiment: I fastened the dead queen with a needle to a piece of cork, and hung it in a cluster of bees. The colony remained quiet, and I knew later on that it had felt entirely queen-right because the comb which it made showed no drone-cells, and the dead queen was surrounded by licking bees.[47] How long a dead queen can supply the place of a living one I am not able to tell.

However, even a dead queen may be dispensed with. In order to do this, I put a weak colony into swarming condition—that is, took away all combs so that the agitation could be more quickly observed. The queen was put into a cage. The next day I took the cage out of the colony, and very soon I noticed the typical signs of queenlessness. When the excitement seemed to have reached its height I opened the glass door and held the cage from which the queen had been quickly taken in the midst of the bees. Immediately it was surrounded by many "joyful" bees with lifted abdomens, fanning with their wings, and the buzzing ceased. Here we have conclusive proof that the odor of the queen is enough to satisfy all the instincts which appear unsatisfied during the excitement over the absence of the queen.

The conclusion may easily be drawn that, if the weak odor adhering to the queen-cage causes a cessation of the agitation, and certainly it is the odor alone, the disappearance of weakening of the same causes the outbreak of the uneasiness. But this deduction does not seem conclusive to me; for, as I have said above, the odor does not disappear with the removal of the queen, but is, however, weakened; and if the colony is vigorous, and their instincts are diverted by a rich honey-flow, the bees notice the loss only after some time has passed. But in the case of the sudden outbreak of uneasiness over the absence of the queen, we have to do with an intensified instinct, for which the shadowy memories in actual requirement are sufficient for the needs of the case, if I may so express it. Thus bees in the spring, impelled by necessity in a region where there is little pollen, will gather the dust from thrashing, coal dust, or brick dust, instead of the lacking pollen. Once I observed bees collecting even sawdust. It is just as little permissible to draw from this the conclusion that brick dust is equivalent to pollen, because bees react in the same way toward both, as it is to conclude that it is the missing odor alone which

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[46] In the original, the author characterizes this peculiar humming as "sterzeln." This he describes in a footnote as follows:

"By 'sterzeln' is meant that characteristic raising of the abdomen, accompanied by a slow whirring of the wings, which indicates joy. Therefore it is seen in the above case, or when they discover the hive after going astray, but never on finding a honey supply, even if very hungry. This is similar to what I might call the attitude of fright. If the finger is approached to the entrance of a hive, single bees guarding the passage are seen to hasten toward the hostile object, raising their abdomens in threatening manner, and they remain in this position.

[47] A queenless colony will erect drone-cells if it builds at all.

causes agitation in a stock, because the bees are satisfied with the remembered odor in place of the real queen. We shall have better proof further on.

BEHAVIOR OF A QUEENLESS SWARM.

As a first swarm was issuing I caught the queen at the entrance of the hive. Now instead, as happens in most cases, of the swarm returning to the hive after the vainly searching circling, the bees hung to a branch united in the well-known cluster. Since no alarm was shown, I took it for granted that a second queen had swarmed with them; but a prompt examination of the hive revealed no queen-cells from which a young queen could have emerged. The swarm was perfectly quiet for over half an hour, then suddenly broke up and went back to the hive—a certain proof that it was queenless. In this case, then, there was a considerable time between the removal of the queen and the breaking-out of the uneasiness over her absence. It was evidently not the disappearance of the odor of the queen that caused the discontent, for the odor was lacking from the beginning. Queenless swarms rarely take place; and if they do, they do not settle and disband again; they miss the queen immediately. Coming out into the open air, the odor of the queen seems to be of little value. This is evident from the fact that if one keeps a caged queen in a circling swarm, it has to remain there for a long time before she is scented by the bees, if she becomes scented at all. But if a bee once places itself upon the cage, "joyously" lifting the abdomen, and humming, then it is not long before the rest are attracted by the sound of the "satisfied" hum. I might, incidentally, mention that there is a so-called "diamond rule" among bee-keepers. This rule is that the queen is to be enclosed in a cage for a short time before and during a rich honey-flow in order to hinder her from laying eggs. The bees then will have little brood to care for; the consumption will be diminished, and the honey store should increase. This, however, frequently does not take place, because the normal condition of the colony is disturbed. The colony often believes itself queenless and builds queen-cells in spite of the imprisoned queen in the middle of the colony; but this phenomenon does not appear in all colonies.[48] Apparently there is here, as has been demonstrated before, an unsatisfied feeding instinct. The nurses can not distribute the richly prepared larval food, and so the impulse is generated to remove the abnormal condition by building queen-cells. I can imagine this as an example of a clear reflex. There is no need whatever for "reasoning" of any kind.

I shall now return to the very vigorous colony mentioned before. If the queen is taken away from such a colony, which compactly filled the brood-chamber and honey-chamber in a large hive, the signs of uneasiness over the absence of the queen will go on as described. When the colony is in greatest excitement, a cage containing a queen may be pushed into the honey-chamber in the upper part of the hive which opens from behind, and then the condition of the bees at the entrance at the opposite end of the hive underneath in the brood-chamber may be observed. Almost at once a change in the behavior of the uneasy bees is apparent; the buzzing dies out in the hive, and the bees, searching around the entrance, enter with lifted abdomens and fanning wings.

The explanation can here certainly not be the influence of the odor, since the odor of the queen could not penetrate in an instant to the entrance which is separated from the honey-chamber by the whole of the brood-chamber. If the extraordinary penetrating odor of female insects be cited, as, for example, that of the moths (sphinx, etc.), then I would reply by referring to the disregard of an imprisoned queen in a swarm.

DISREGARD OF A QUEEN IN OPEN AIR.

In order to demonstrate this question still further I hung a cage containing a queen on a stick and stuck this into the ground so that the cage was at the same height as the hive entrance, about thirty-five centimeters to one side of the flight-board. None of the

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[48] It is curious that queen-cells are also established if the queen is decrepit. If, therefore, queen-cells are found, and at such a time either strongly defective brood or drone brood in worker-cells (on account of the exhaustion of the supply of sperm-cells), then one can be sure that the old queen will shortly disappear from the hive. Perhaps the same instinct is active here as in the case of an imprisoned queen (see footnote, p. 11).

numerous bees flying in and out scented the queen, which remained entirely unnoticed while the colony continued agitated.

HEARING CAPACITY AND SENSATIONS OF SOUND.

If we now conclude from the foregoing observations in what way the discontent because of the absence of the queen, as well as the content because of her presence, is communicated, and what the means of communication are, we must conclude that the odor is not the only factor. We have been able, on the one hand, to determine with reasonable certainty that, if the odor were sufficient to inform the colony of the presence or absence of the queen, no other special kind of communication need be used; on the other hand, we saw indications of discontent (for example, the building of queen-cells) among bees when a queen was present in a cage. So we see signs of peace or agitation in cases where the influence of odor seems completely excluded. In all observations, when the colony notices the absence of the queen there is always a change in the usual characteristic sound in the hive, the bustle of the colony, if I may so express it.

There is, therefore, not the slightest doubt in my mind that bees communicate with each other by sound. The tone of "peace" attracts hive mates or quiets them; the louder buzzing excites them; it disappears if the queen is given back. At the same time the whole character of the colony changes,[49] the queenless irritable bees become quiet and peaceful, and again take up their work, which was laid aside during the excitement. We must admit the possibility of communication between bees by sound, therefore of hearing capacity and sound sensations.[50] Each bee has the instinct to join in the tone of discontent if it hears it; therefore if the absence of the queen is noticed by one bee the agitation is very quickly propagated throughout the colony.

How the first notice of the lack of a queen takes place is naturally, as before stated, very difficult to determine—perhaps there are several possibilities. Often the absence of the queen odor may bring about the result; it may be the absence of the characteristic humming described, which the bees occupied with the queen produce. Further, it is possible that the queen herself makes sounds, the absence of which is noticed. I have never heard such a humming, but it is not impossible that such tones, not perceptible to the human ear, exist.

EXPERIMENTS ON SWARMS.

The following observations will show to what a great extent the means of communication between bees depend upon sound perceptions. The loud buzzing of swarms is readily distinguished from the usual hum by anybody who has been occupied with bees for any length of time. The swarm presses out from the hive in impetuous haste in the peculiar swarm dance; it surges and whirls in "bacchanal delight," as if the bees were really drunk with "joy." The "swarm dizziness," as bee-keepers say, has seized it. In this dizziness it forgets everything connected with the old dwelling, and bees even forget to sting.

"Swarming bees do not sting" is an old bee-keepers' saying. From this we get the old fable that bees recognize the bee-master, because, generally, outsiders approach a bee-hive only to see the interesting spectacle of a swarm, and then notice the bee-keeper, often quite unprotected, quiet and composed, stand in the middle of the tumult without being stung.

The "Deutsche Bienenfreund," 1894, reports the following: "A boy about ten years old was standing near a hive, bare-headed and shirtsleeved, when a swarm issued. After flying here and there, the queen alighted on the boy's head, and thousands of bees quickly

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[49] Careful observation will show that every colony has its particular character, which is determined in part by the strength of the colony. On the other hand, we often see what are apparently great differences in colonies of like strength. One colony is gentle; another constantly desires to sting. One defends its hive entrance carefully; another almost not at all, although it is a strong colony. One flies constantly earlier than its neighbor, etc. Lubbock and Herman Muller have shown that individual bees vary also. (Herm. Muller, "Versuche uber Farbenliebhaberei der Honigbiene," Kosmos, Jahrg. 6. Lubbock, "Ants, Bees, and Wasps," German translation published in Leipzig, 1883, English edition in the International Scientific Series, New York, 1883.)

[50] In the attraction of a queenless colony into the hive of a queen-right one, then, perhaps, in the first place the hearing capacity comes into question (see p. 5), the sound of the contented humming acts as a powerful stimulus and causes the migration.

followed. The boy's father, recognizing immediately the state of affairs, called to him hastily (he had often looked on during the catching of a swarm), 'Do not move, Hans. Shut your mouth and eyes, and breathe through your nose. I will sprinkle and capture them!' The boy obeyed, the father poured water over his head, bent it forward, and with a feather stroked the whole swarm into a basket underneath. The boy had not a single sting.''

After my own experiences, I consider this tale entirely trustworthy.

In 1893, ''Studers ill. Schweizer. Bienenfreund,'' showed the picture of a young bee-keeper who had been photographed with a swarm which hung down from his hand. In the issue of the swarm he caught the queen with his fingers, thus causing the swarm to surround his hand. When the photograph was completed, three-quarters of an hour had elapsed, which was endured very quietly, the arm being supported with a stick. Head and hands were not stung. Similar pictures have been published in ''Gleanings in Bee Culture'' during the last few years.

It is not in contradiction to the above to say that most disasters are caused by swarming bees; for nervous blows or accidental crushing irritates the swarming bees; and first one sting, then hundreds follow, excited by the strong odor of the poison.

Shortly before the issuing of the swarm, single bees are seen coming out with uneasy motion; they press through the bees around the entrance, which often cling closely together like a long ''beard'' hanging from the flight-board. It can hardly be doubted that sounds of some kind perhaps serve here for communication—sounds lost to the human ear in the general hum;[51] at least there is no more plausible explanation for the peculiar result, for suddenly the ''beard'' loosens, the bees enter the hive quickly, assail the honey stores, and fill their honey-sacs. All the others desiring to swarm do the same thing, and suddenly the swarm breaks forth. Those just returning from the fields heavily laden with pollen are involved in the tumult, infected with the sound of swarming, and fly with the swarm.

THE INFECTING INFLUENCE OF THE SWARM TONE.

That the sound made in swarming, which is given only in flight, is infectious is well known; for now and then it happens that the neighboring colony, though not nearly ready to swarm, will follow the swarm-tone and swing into the air. If two swarms issue at the same time, they mutually attract each other and unite.

That we have here to do with a chemical reflex, as is thought by Bethe, who, strangely enough, does not take swarming into consideration, seems improbable to me. If the rich possibilities for sound communication between bees are borne in mind, it is evident that this capacity must have some object, and that it is not practicable to ignore these data.

THE ENTICING NOTE OF BEES.

If a swarm is shaken out on a sheet spread over the grass, and a hive never before used is placed, for instance, on the north side of the sheet, it will remain unnoticed if it has not come in direct contact with the swarm. But if a handful is scooped up and thrown at the entrance, they will immediately draw near with specially loud humming, part standing outside, however, on the flight-board with lifted abdomens and wings fanning. All the other bees near by turn, if they have been facing away from the hive, and follow the alluring sound, lifting their abdomens and fanning with their wings. More keep following, and a broad band march into the dwelling. If now the hive is taken away and placed on the south side, the bees quickly march on further north, but for only a short time. Then the increase of the attracting note from the south causes a gradual turning of the stream, which enters the hive little by little. It may happen that a little cluster of bees advances firmly northward, although many mates turn toward the south. The alluring tone does not seem to penetrate further; they heard it coming from the north and follow the memory. There seems to be no other explanation for this course. In my opinion the fact that not only a single bee but plenty of them, a small cluster, follows this

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[51] Movements of the antennæ should certainly be considered, since the play of the antennæ is always lively, and often a mutual touching takes place.

memory is a proof of the impulse for imitation which is undoubtedly present in bees for it is not likely that every bee in the small cluster has this memory but perhaps only a few of them. The others follow only on account of this impulse for imitation. If the first bees remain true to the direction, then a great number will turn quickly with them.

It must really seem strange, to any one familiar with the natural history of the bee, that there can be any doubt as to the possibility of communication through sound, when the whole life of a bee is one continuous humming, if I may so express it. Can this "audible speaking" have no purpose? Only the dead bee is quiet.[54]

If the previous assertions are not convincing, we may find proof of their capacity for hearing in the following:

THE "TEETING" AND "QUAHKING" OF THE QUEEN.[55]

When the first swarm has issued with the old queen, normally nine or ten days pass before the after-swarm follows. One or two days before the swarming, a strange concert may be heard in the hive on a quiet evening at a distance of a couple of steps. It is the "teeting" and "quahking" of the young queen. As is well known, the old queen, before her exit, lays eggs in the queen-cells at intervals every day or so; the consequence is, that the young queens do not all emerge at once.

The first queen to emerge falls upon the other queen-cells in order to kill her rivals. If the colony wishes to swarm, however, the workers prevent this destruction, and the queen begins to "teet" in "jealousy." She presses her head against the comb, as I have observed, and sounds a clear, ringing, long-continued "teet, teet," apparently using the stigmata on the thorax. Immediately the most mature of the queens still in the cells answers with a short deep "quahk, quahk." Thus this interchanging goes on for hours or days with shorter or longer interruptions. If rainy weather prevents the issuing of the swarm, and more queens mature, they "quahk" likewise. They "dare" not emerge as long as the "teeting" goes on; and since they need nourishment they cut a little slit with their mandibles, through which they stick their probosces, and so are fed by the workers. It would lead me too far to go into these interesting circumstances.

If we can prove from the above an undoubted capacity for hearing, we can also from the following experiment:

THE QUEEN'S TONE OF FEAR.

If a strange queen is put into a queenless colony by merely allowing her to run in upon a comb, then the bees nearest her fall upon her and bite her legs or ride upon her to sting her. The powerful queen runs quickly away from her persecutors, but she is continually seized by others. Now in her "fear" she utters loud cries which throw the whole colony into excitement. One could here conjecture the influence of odor; but a strange queen in a cage does not cause such excitement, especially not if the colony is queenless. It is doubtless the tones of fear which stir up the whole colony. We have here again an unmistakable reaction toward sound-sensations.

The attempt might be made to weaken these assertions, so far as they apply to the existence of hearing capacity, by pointing out that no one has yet succeeded in showing in insects a reaction toward sounds artificially produced. Then I would call to notice that recently an American has obtained undoubted reactions toward the notes of tuning-forks in two members of the Formicidæ[56] (*Lasius Americanus* and *Formica nitidiventris*) in the two Myrmicidæ (*Crematogaster lineolata*, and a kind of Aphœnogaster). The well-known myrmecologist William Morton Wheeler has meanwhile published in an important paper (Ethological Observations on an American Ant, Journal für Psychologie und Neurologie, Bd. II., Heft 1 u. 2, Berlin, 1903), his investigations on hearing in ants. He writes as follows:

"Stridulation, at least among the Myrmicidæ, Poneridæ, and Dorylinæ is an impor-

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[54] 1. Ernst Haeckel, Die Weltratsel, Bonn, 1899, p. 145.

[54] 2. Now and then the colonies settle down in their winter sleep into a condition of complete quiet, but usually it is accompanied by a hardly audible murmur.

[55] It is, of course, very difficult to represent these sounds in words; but the ones here given are often used in English to represent them. No bee-keeper will have any difficulty in knowing what is meant. The author represents them in German by the words "Tuten" and "Quaken."—E. F. P.

[56] Science (The Sense of Hearing in Ants), No. 5, Vol. X., No. 256, 1889. See also my Conclusions.

tant means of communication, which Bethe has completely ignored, and even Forel and other Myrmecologists have failed to appreciate. It readily explains the rapid congregation of ants (Myrmicinæ) on any particle of food which one of their number may have found, for the excitement of finding food almost invariably causes an ant to stridulate and thus attract other ants in the vicinity. It also explains the rapid spread of a desire to defend the colony when the nest is disturbed. This is especially noticeable in species of *Pheidole, Myrmica,* and *Pogonomyrmex.* It is the secret of being able in a short time to catch ants like *Pogonomyrmex molefaciens* in great numbers by simply burying a wide-mouthed bottle up to its neck in the mound of the nest. An ant approaches and falls into the bottle. It endeavors to get out, and, failing, begins to stridulate. This at once attracts other ants which hurry over the brim and forthwith swell the stridulatory chorus till it is audible even to the human ear. More ants are attracted, and soon the bottle is filled. If it be corked and shaken for the purpose of still further exciting its contents, and then held over another *Pogonomyrmex* colony whose members are peacefully sauntering about on the dome of their nest, the wildest excitement will suddenly prevail, as if there had been a call to arms or—to dinner. Even more remarkable is the stridulation in a colony of *Atta fervens,* the Texan leaf-cutting ant. Here the different ants, from the huge females through the males, large soldiers and diminishing casts of workers to the tiny minims, present a sliding scale of audibility. The rasping stridulation of the queen can be heard when the insect is held a foot or more from the ear; to be audible the male and soldier must be held somewhat closer, the largest workers still closer; whereas the smaller workers and minims, though stridulating, as may be seen from the movements of the gaster on the postpetiole, are quite inaudible to the human ear. It is not at all improbable that all this differentiation in pitch, correlated as it is with a differentiation in the size and functions of the various members of the colony, is a very important factor in the co-operation of these insects, and of ants in general. The contact-odor sense, important as it undoubtedly is, must obviously have its limitations in the dark subterranean cavities in which the ants spend so much of their time, especially when the nests are very extensive like those of *Atta.* Under such conditions stridulation and hearing must be of great service in maintaining the integrity of the colony and its excavations. The fact that as yet no unquestionable auditory organs have been discovered in ants is of secondary importance when it can be so easily shown that these insects really respond in an adaptive manner to the sounds produced by other members of the colony.''

I know very well that Miss Adele M. Fielde and George H. Parker are of the opinion (The Reactions of Ants to Material Vibrations, Proc. Acad. Nat. Sc., Philadelphia, Sept., 1904) that ''it is misleading to ascribe or deny hearing to ants; they are very sensitive to the vibrations of solids, not to those of air; their reactions could be as appropriately described as resulting from touch as from hearing.'' But the above investigations on bees have been neglected by these authors, and I am still of the opinion that a sensitiveness to the vibrations of air can not be denied so far as bees are concerned, and the above experiments of Wheeler seem to show the same in ants.

MEMORY OF PLACE IN BEES.

> In general, we should not set up a new unknown force to explain natural phenomena until it has been proven that they can not be explained by the known forces.—*Aug. Weismann*, p. 539.

According to Bethe, bees are "led back to the hive by a force entirely unknown to us. This force does not adhere to the hive itself, and it does not lead bees back to the hive itself, but to the place in space which the hive usually occupies. It does not act at boundless distances. It is an old experience of bee-keepers that they can take a colony to another stand without fearing that the bees will return to the old place, if the new spot is only more than six kilometers from the old. It follows, then, that this force acts at most at a distance of six kilometers, since the impulse to return to the hive is the strongest of all impulses in bees. But I believe that the zone of action of the force is not a circle with a radius of six kilometers, but of only between three and four kilometers. If the circle had had a radius of six kilometers, then the bees of the transported hive would be back into the circle of action if they got more than half that distance near the old position in foraging, and would have to return to the old place. But this only happens if the old position is less than six kilometers away from the new. We must, therefore, accept something near three kilometers as the boundary for this circle of action for this force." (Bethe, l. c., p. 89.)[57]

I believe that the foregoing, and likewise in many other of his observations, Bethe furnishes such excellent proof of the existence of memory for location that one can hardly wish anything better. But Bethe supposes "a force unknown to us," with which we do not know what to do, which offers support for every investigation. Under this head I must depend more strictly upon Bethe's work in order at the same time to point out the errors in the chapter, "How do Bees Find the Hive?" (Bethe, l. c., p. 72.)

THE "PATHS" OF BEES AND THEIR DIRECTION.

If the bee-hives are placed on an open heath, with no elevations such as trees or bushes, the particular kind of flight toward and away from the hive may be studied, undisturbed by local conditions. In August, 1898, I had opportunity to prove this condition on a moor in the neighborhood of Oldenburg, corroborating entirely my earlier experiences.

The colonies were established on the moor by the bee-keeper shortly before the buckwheat-flow. The hive-entrances faced the east. On the first day the flight was weak, for as yet there was nothing to gather. The bees flew out irregularly in smaller or larger circles in all directions. There was nothing to be seen yet of "a path."[58] Great buckwheat-fields stretched toward the north as well as to the south. When the flowers opened, the mode of flight changed. Part of the bees flew from a point close to the entrance, sharply

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[57] The "unknown force" must act at much greater distances under certain conditions, for other observations show that bees have flown five, six, or even over seven kilometers further under extraordinary circumstances. (See Bienenzeitung, X., No. 14; ditto III., No. 9, Dzierzon; Le Rucher, Amiens, 1876, IV., p. 30). In these cases there was no forage near at hand. According to Dzierzon, some bees under these circumstances scented a large "hundred-acre" rape-seed field which lay far outside their usual circle of flight. Roth, the leader of the Baden school for bee-keepers, in Durlach, observed that some of his bees returned in thirty minutes with full loads from a buckwheat-field six kilometers away. Granting that Roth's bees flew to the buckwheat-field from the south, there is no reason for thinking that bees from an apiary at the same distance toward the north had not hastened to this same nectar supply. Now if, for experiment, a colony should be taken from the southern apiary to the northern one, then they fly south to the buckwheat-field, and there, coming into the field of action, would again return to the southern apiary. The "unknown force" would reach twelve kilometers in this very possible case. If it be asked from what distance bees can find their way back, the answer can not be made in kilometer measurements, for it depends upon whether the bees are in their flight or orientation (see the same) or in their search for food have flown to greater or less distances, upon the definite direction of the forage and the general orientation.

[58] "It is well known that, in front of the entrance to a strong colony, there is always a long dark cloud formed by the bees constantly going back and forth." (Bethe, p. 75.) This is Bethe's "bee-path."

to the left (north) and another part sharply to the right (south). In consequence of this the paths were very short, the terminations (the hives stood close to each other) coming together in a common wave.[59] It is apparent from this that the position of the pasture determines the direction of the flight in and out.

When, later, the buckwheat-fields ceased blooming and the moor was in full bloom, the same short, though perhaps a little lengthened, paths were seen; but the common wave was higher and apparently somewhat larger, from the great numbers hastening in from all sides.

"Long paths" of bees, which Bethe describes as normal, are found chiefly only in the case of bees in gardens where trees, houses, etc., modify the flight. The view is wrong (Bethe p. 80), that "it is a well-known fact to bee-masters that the steepness of bee-paths varies with the weather."[60] It is an error further, that "bee-paths always go out from the hive in the same direction with slight fluctuation. This is almost always east, southeast, or south. Not only for this reason, but also because bees need sun to be industrious, the bee-keepers place their hives toward the south or east." (Bethe, p. 81.) This last assertion is erroneous.[61]

It is clear from the above, even if Bethe had not stated it himself exactly, that there was nothing in the north for his bees to gather, since they never flew north (see Bethe's following conclusions). In that case the town (Strassburg) must spread out northward from the place of Bethe's investigations. Bethe supposes that the town remained "unknown" to the bees.

The garden of the Physiological Institute in which my bee-hives stand lies close to the town wall. The wall is covered with green, and behind it stretch great blooming meadows which teem with bees. On the other side of the Institute lies the city. There are very few and very small growing plants in the city; and, in spite of many searches, I have only once seen bees in the inner part of the town, on two isolated sunflowers. At all events it must be admitted that only a few isolated individuals have been in the interior of the city at any time in their lives, particularly as my bees always fly toward the south to the meadows." (Bethe, p. 86.)

I must consider these assertions also as erroneous and not conclusive, for the handler of sugar wares, honey-sellers, gingerbread bakeries, and housewives who leave sweet preserves or jars of honey in the open windows well know they have to count upon much unpleasantness from visiting bees.[62] There is not always something to be gathered from the meadows (pause in the honey-flow, the cutting of the field); and, besides that, bees in their first flight, which is devoted to orientation, orient themselves not only toward the side of the pasture but naturally on all sides.

Bethe then let bees fly in the streets of the city, only within the short distance of 350, 400, and 650 meters from the hive, in spite of the "unknown force" which acts, according to Bethe, within a distance of three kilometers. Because, when let go, these bees found their way home just as well as those from the meadow, he decides that "there

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[59] I noticed that bees of one and the same hive followed both directions.

[60] I admit that the French boy learns in his lesson:

"Quand les abeilles volent en haut
Nous aurons bientot de l'eau."

But this probably national idea is just as wrong as the one that a hard winter is to be expected if bees propolize entrances strongly. In general, many statements to be found in the literature on bee management should be taken with prudence. Safe judgment can be made only after a personal experience of many years.

[61] Dathe, Lehrbuch der Bienenzucht, 5 Aufl., p. 34, and following, Bensheim, 1892: Berlepsch-Lehzen, "Bienenzucht," Berlin, 1899 p. 28 and following; "Bienenzeitung," 2 Ausg., Nordlingen, 1861-'62, 2 Bd., p. 3 and following; v. Berlepsch, "Die Biene und die Bienenzucht," Muhlhausen, 1860, p. 219 and following; Dzierzon, Rationelle Bienenzucht, Brieg, 1861, p. 36, etc.

[62] Because of this kind of trouble, bees are forbidden in the precincts of the city of Paris. The Bw. Centralblatt, No. 19, 1899, announces: "In a small city a broker had stored comb from colonies with foul brood in a room accessible to bees. The following year almost all the apiaries of the city were infected," etc. During the dearth of nectar, specifically in Bethe's case, the flying in the town where there was always something at which to nibble might have been more vigorous than to the fields where nothing could be obtained. Moreover, Bethe himself furnishes a good reason that bees flew extraordinarily accurately through the city, for he asserts that he "had seen bees inside the city upon two isolated sunflowers." How very inquiring the bees must have been to find a single flower! We can be very sure that innumerable bees (even if not seen by Bethe) followed the same instinct which drew these sunflower visitors into the city, for there are no recluses among bees, none which separate themselves from the masses to follow a way of their own, and all possess the same kind of instincts. A single linden-tree in bloom in the city is enough to attract hundreds of thousands of bees.

can be no doubt at all that bees find their way back to the hive, *not* by means of memory pictures'' (Bethe, p. 89).

I cannot find in the foregoing the slightest foundation for this view of Bethe's. If he wishes to disprove the investigations of Romanes,[63] then I think the attempt is unsuccessful, for Bethe leaves to us the proving that the city has remained actually ''unknown'' to the bees.[64]

But how is the mysterious behavior in the streets explained? We shall let Bethe speak for himself: ''All bees, if let fly, go upward in a corkscrew line, then suddenly take a direction and fly off in a straight line. This happens when bees are let fly in the city streets almost always before they have reached the levels of the house roofs. It often happens at a height of four to six meters above the street level, therefore generally before they can have acquired a view of the neighborhood. Now, almost without exception, they take the direction of the Institute, where the hives are.''

Before I give the explanation for this, other parts of Bethe's account continue: ''Light is the incentive to flight in these diurnal animals'' (Bethe, p. 83); further, ''Light regulates flight.''

I remember, too, in Herm. Müller's investigations that he could carry a bee in a drinking-glass open beneath, the length of the garden without the bee flying out, for it constantly pressed to the top of the glass toward the light.[65]

I slipped a bee into a reagent glass and put it upon the window-sill so that the bottom of the glass was toward the window. For eight hours the bee strove inside the glass in vain efforts to reach the light. Then it died, although it would have been easy to crawl out of the open tube and fly out of the open window.

Now, if we remember that the city lies to the north of the seat of Bethe's investigations, we shall see that the sun must be in the direction of the Institute, and the bees were let fly in ''quiet, sunny weather'' (Bethe, p. 87). In the darker streets, perhaps unknown to them, they tried to orient themselves by mounting in circles, just as a carrier pigeon does.[66] Then they fly instinctively toward the bright source of light (just as in a room they fly unfailingly toward the bright window) until they become oriented in familiar regions. ''Light regulates flight'' (Bethe, p. 83).

I, therefore, can not consider the ''unknown force'' and the conclusions based on it as capable of proof.

I have held to Bethe's assertions with regard to these directions. From them I understand that on one side of the Institute toward the south are the meadows; and on the other (therefore toward the north) is the city. Possibly Bethe did not liberate the bees just in the center of the city but toward the edge, so that the Institute was shifted from its southern position a little toward the west or east. Further investigations might be necessary, perhaps, to prove that these bees did not return to the hive not through the ''unknown force.''

We learn from Bethe (l. c., p. 87) that eight marked bees were let fly in the city

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[63] Romanes, Nature, 1885, Vol. 32, p. 630, Homing Faculties of Hymenoptera.

[64] That Bethe's idea that bees had not been flying in the city is not at all convincing, follows from something written by the editor of "Elsass-Lothring. Bienenzuchters." Karl Zwilling, which reached me subsequently. In my publication in the "Biologischen Centralblatt" the same is given, therefore, in a later passage. I quote the following: ''* * * Outside of Strassburg there are many apiaries close to the wall, the bees of which never think of flying into the city except in times when there is no forage. Then they enter the candy factory of Mr. Pale, Tiergarten Strasse, and annoy the workers as well as partake of the sweets. Even in the month of December, 1899, in the warm sunshine I observed bees flying in the middle of the city on the Kleberplatz, where hundreds of pots of flowers were displayed for sale. There they gathered honey and pollen. Every year some swarms fly into Strassburg and hang on the chestnut, linden, oak, and locust trees found in many parts of the city, and once a swarm hung on the showcases of a glovestore near the cathedral. When the trees bloom, bees fly about them vigorously. In the interior of the city there are beautiful rows of chestnuts along the Ill, rows of lindens around the Kleberplatz, etc., all of which are sought out by the bees when they are in bloom. The honey-venders and those who deal in sugar wares are not molested if they keep their wares covered. As I live in the neighborhood of Strassburg (ten minutes by rail), and have been President of the Bienenverein there for thirty years, I know the conditions exactly."

[65] Herm. Muller, Versuche uber die Farbenliebhaberei der Honigbiene, Kosmos, Jahr. 6, p. 276, 1882.

[66] H. E. Ziegler, Die Geschwindigkeit der Brieftauben, Zoolog. Jahrb., X. Bb., 1897, pp. 99, 278.

on a quiet sunny day at distances of 350, 400, and 650 meters from the hive. The result is as follows, from an observation of twelve minutes at the hive entrance:

Distance of 350 meters.		Distance of 400 meters.		Distance of 650 meters.	
1.	1½ min.	1.	5 min.	1.	4¾ min.
2.	2¼ min.	2.	7 min.	2.	5¼ min.
3.	2¼ min.	3, 4.	10 min.	3.	5¼ min.
4.	2¼ min.	5-8.	? min.	4.	7½ min.
5.	2¾ min.			5.	9 min.
6.	3½ min.			6, 7.	10½ min.
				8.	? min.

This time experiment alone proves that there can be no explanation for an "unknown force" which "draws to the hive like a magnet;" for if it really existed these great differences in time would be entirely inexplicable. Since there was no wind, and the sun was shining, there were no hindrances to flight, and the bees ought to have reached the hive-entrance in the shortest period and at the same time. Further, supposing the existence of an unknown force which draws bees back to the hive directly, the length of time for flight is in itself too long, because bees fly very quickly. A carrier pigeon would undoubtedly cover the same distance in question under the same favorable conditions in eighteen, twenty-four, and thirty-nine seconds, if we use as proof the calculations of Ziegler on the swiftness of carrier pigeons.[67] Their flight is found to be often as swift as 1000 meters per minute. If we now take the flight of bees to be half that, 500 meters per minute (a velocity which has been directly observed by Cowan[68]) then the "unknown force" should have led the bees back in thirty-six, forty-eight, and seventy-eight seconds. If we double the time because the bees in the experiment were carrying honey,[69] the time would be normally about one minute twelve seconds, one minute thirty-six seconds, and two minutes thirty-six seconds. Comparing this with Bethe's table we find a striking difference which is unintelligible if we accept the idea of the "unknown force," but this difference is easily explained if we consider that the bees had to orient themselves with their eyes, and that they at first made errors in direction so that they found the hive singly after three and one-half, ten, and ten and one-half minutes had elapsed.

Of the nineteen bees which were let fly from a courtyard into the street, Bethe observed that seventeen of them ("at about half the height of the houses," "before they flew as high as the roof") "took the exact direction" for the hives at the Institute. That these bees probably followed only light stimuli in taking this direction I have said before, for that they really did not return directly to the hive is shown by the above table. If all the bees, "almost without exception," which were set free in an "unknown neighborhood" under the conditions cited, took "exactly the right direction," they would have come in very much more quickly.[70] I would here refer further to what I incidentally work out from the box experiment (see p. 25).

The "unknown force" does not lead the bees back to the hive, but, Bethe suggests, to the place where the hive stands or has usually stood. Is not this memory of location? What does Bethe understand by the "unknown force"? We receive no explanation. He thinks it is a power lying outside the bees which draws them to this place in space as a magnet draws steel" (Bethe, p. 93). He has made no investigations to find out whether this unknown force is connected at all with any organ of the bee.

But we shall attempt to get nearer to this mysterious power.

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[67] H. E. Ziegler, Die Geschwindigkeit der Brieftauben, Zoolog. Jahrb., X. Bd., 1897.

[68] Thos. Wm. Cowan, The Honey-bee, its Natural History, Anatomy, and Physiology." London, 1890: German edition, Braunschweig, 1891.

[69] "One can not take any bees at all for this experiment; but such as come into the hive laden must be chosen, for otherwise we have no guarantee that the bees will come home by the shortest way and not go foraging first." Bethe, l. c., p. 87.

[70] The assertion that bees would fly directly to the hive, but that on the way they alighted at any time, then flew again in the direct line, is in contradiction to the habits of bees. They fly many kilometers without resting.

DISAPPEARANCE OF THE MEMORY FOR LOCATION THROUGH NARCOTIZATION.

If bees are deafened with chloroform, ether, saltpeter, puff-ball, etc., the memory for location entirely disappears. After waking from the stupor they may be taken from the hive and they will not fly back to the place in space in which they are "accustomed to find it." They no longer recognize their own home nor the place where it stands; they have forgotten everything previously known. But an animal that can forget must have possessed something to remember. The memory pictures are wiped away. We see that the "unknown force" is identical with the memory for location which builds up memory pictures.[n]

It is necessary to mention that bees which have been stupefied become entirely normal again—that is, they orient themselves with regard to their new home, and gather new memory pictures by which they find once more the places for nectar and pollen as well as their new hive.

Bees, therefore, have capacity for learning—a fact which Bethe disputes.

Let us look more closely at the quintessence of Bethe's investigations. Upon pages 81 and 89 he formulates the view about the "unknown force," the counterpart of which is stated in this chapter (see p. 19). On page 94 we find further conclusions in the following words: "Yet I must repeat: Bees follow a force which is entirely unknown to us, and which causes them to return to the place in space from which they flew. This place is usually the hive, but it need not necessarily be. The influence of this force reaches over a circle of only a few kilometers."

But here we have no "repetition" of what has been said, but something that, on closer examination, shows statements which are contradictory among themselves, and which contradict earlier assertions, if one takes into consideration the observations which Bethe uses in formulating this conclusion (Bethe, p. 93). We shall now look somewhat more closely at these observations.

THE BOX EXPERIMENT.

If the unknown force acts at a distance around the hive of only three or four kilometers, as Bethe asserts, then all the bees of this colony which were set free within this circle must return unresistingly to the place from which they flew which "draws like a magnet." But this is not the case, as Bethe himself proves in the experiment given on page 93. He says: "In my first experiment with letting bees fly from other places I observed the following: I placed the box, in which the bees were transported, on one of the large pieces of sandstone lying around in a stone-cutter's yard and opened the lid. The bees all flew out; and most of them, after a few circles in the air, went in the direction of the Institute. Two bees mounted to a height of about three meters, made a few circles of four or five meters in diameter, and then alighted on the box. I drove them away into the air again. They flew in large circles around it, and then again lighted on the box. Now I took the box away and put it on another stone, having driven the bees into the air once more. Both bees flew so high that I could no longer see them; but a few seconds later they sank again and gradually flew around the place where the box had stood."

We see, then, that a few bees were influenced by the unknown force, but others were not. This changing condition Bethe can not and does not attempt to explain.

That the bees alighted on the stone where the box had been (which fact Bethe tells with astonishment) is very easily understood, and furnishes further proof of the excellent sense of locality in bees, for their admirable orientation with their eyes. Bethe's objection, "if they had been influenced by chemical or light reaction, then they would have flown to the stone only two meters distant, and easily visible, on which the box was placed. But they flew back to the place from which they had flown," signifies anthropomorphism brought in in its highest potentiality. It is not possible to conclude for bees that they would look for a box two meters away, which before had stood in the other place. Their

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[n] I might ask our ant-investigators to take up similar experiments with ants. It would be of great interest to know whether a similar condition can be demonstrated.

memory of locality leads them with infallible certainty back to the place they had impressed upon themselves by the circling orientation.

But why did these bees not fly back to the Institute if they possess such an infallible sense of locality? For the simple reason that they were young bees which had not yet developed their orientation by flying out, or perhaps old ones that had not taken their orientation flight till to this spot. No one who is thoroughly familiar with the nature of bees can have the slightest doubt about it.[72]

But because of these experiments and others, Bethe was forced to take this position in formulating his final conclusions: "The unknown force causes the bees to return to the place from which they flew," and, therefore, to modify his earlier declaration that they return "to the place in space where they are accustomed to finding the hive." The box experiment can not explain both the habitual return to a dwelling and a single return to a place. The return to the place from which they flew takes place in those bees which returned to the box and not in those which did not "return to the place from which they flew" but turned toward the Institute. I must confess that I find no logic in these contradictory statements.

Yet hear Bethe further: "I often repeated these experiments later. The further away the bees were taken from the hive, the fewer returned to it; the more flew back to the place from which they had flown.[73] I chose open fields for these experiments where there were no large objects by which the bees might orient themselves optically. The box was taken up immediately after the bees had flown out. I marked the place in the grass accurately and stepped back a few steps. The bees returned with accuracy, and made scarcely a mistake of more than a few decimeters. Many trod exactly upon the spot. Often they stayed in the air for a minute, then returned. Once I noticed a bee alight on some salvia in the meadow to take nectar there; then it flew away again and then returned to the place from which it had flown. It was most startling to me when I held the box open in the air until the bees had flown away and then stepped aside a few steps. Four or six bees, after circling in the air, returned to the very spot where I had held the box, making small circles at about the height of a man."

I can only remark here that, even if there were not objects in the meadow optically discernible to human eyes by which they could orient themselves, there may have been innumerable landmarks for bees. No one will doubt this who knows anything about the wonderful certainty (far surpassing human ability) with which bees in swift flight pick out their own homes among hundreds of bee-hives placed close together and of bewildering similarity. And if Bethe could manage without marking accurately the place "in the air" (which I must say to my shame I did not succeed in doing in my control experiments, in spite of eyes which are sharper than ordinary), then the bees might have been able to do it too. In order to give the bees the least possible clue (the height of a man) I did not stand but lay down and noted approximately the large circles of searching bees in the air in the direction of the place from which they had flown. I can, therefore, find no support in the experiment of Bethe for an unintelligible "unknown force." Moreover, a few other control experiments gave such interesting and divergent results that I must enlarge further upon them.

I let a few bees fly from a box placed on the short grass of a wide meadow, approximately five hundred meters from the apiary. I quickly stepped a few paces to one side, greatly changing my position, as I did also in the following experiments. The bees

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[72] I might point out in this connection that we see an analogous condition in carrier pigeons. In Prof. H. E. Ziegler's writing already cited, we find the following abstract, Ueber die Orientierung der Brieftauben: "After all I have read and heard of the flight of carrier pigeons, I am of the opinion that their orientation depends upon memory alone, and that it is unnecessary to ascribe it to a mysterious sense of direction." If pigeons are taken away to a place where they no longer have any point of orientation they take up various directions and some make mistakes. The fanciers' society will not undertake to send out pigeons from a distance for which they are unprepared, for in that way there is constantly a greater or less loss of good pigeons. "The pigeon-fancier drills his pigeons in established routes, and thus takes them by degrees to places further away, always in one direction." Also, pigeons can orient themselves in fog and darkness just as little as bees can.

[73] This statement coincides excellently with the foregoing statements against the existence of an unknown force. The logical consequence from this assertion is that the "unknown force" compels bees to fly in two different directions—to the hive and to the box; the one here and the other there. This, to be sure, can not be brought into harmony with what Bethe before considered the influence of the unknown force, nor with the assertion that the "impulse to return to the hive is the strongest of all," etc.

mounted slowly in widening circles, but keeping very low on the whole, at perhaps twice the height of a man. After a minute one bee returned to the box; in one and a half minutes, a second came. Then I drove both these off and took the box away. During the next minute none returned to the place where the box had been, but I saw a number zealously seeking, flying close to the grass in large circles, then flying a little higher. Suddenly, for some unknown reason, numerous bees in a second box under my coat buzzed loudly and almost immediately the searching bees buzzed around me (I was standing in the direction of the wind) so strikingly that my companions beside me exclaimed, "They have heard the other bees." Although I now replaced the box to its former position it remained disregarded; but whenever we went in the near neighborhood the bees followed us, and some alighted on my shoulders, hat, and coat. When I went further away my companions were surrounded, although they had no bees with them. It is noteworthy that the bees in the second box belonged to another colony.

I shall now describe the second experiment. The other box was held up high; the inmates about thirty or forty in number circled in a small radius for a long time, then gradually made larger circles. Some worked in a more up-and-down fashion, close to the box, continually turning the head toward it, just as in the first orientation flight from the hive, about which I shall speak more in detail further on. About half a minute after I took the box and drew back quickly, trying to impress accurately on my mind the spot at the height where the box had been. Two bees appeared in a few seconds, but in a place a little to one side; and then, after making large circles, disappeared again. The chief thing to be seen was the irregular search which they all carried on together after a few minutes in ever narrowing circles,[74] apparently flying close over the ground about two meters from the place where I had stood. The bees were no longer seeking the box, but their home, the entrance of which (according to my estimate) was just at the height above the ground of the circles which they were making. I can give no other explanation for this singular phenomenon. After the bees again wandered aimlessly for some time, flying around us part of the time as described earlier, they followed us homeward for about twenty paces, then turned back. That proportionately few flew back to the apiary is explained by the fact that the bees shortly before had come from the moor, and in the cool autumn weather could hardly have flown out, so that an orientation from the apiary was not yet possible. The day of the experiment was sunny, with a moderate southwest wind.

The striking occurrence, that my companions and I were so thickly surrounded, can be interpreted in so many ways that to explain it would lead us too far.

In the foregoing I see many proofs for the existence of memory for locality; but all these box experiments are untrustworthy, since the investigations go on under entirely abnormal condition for the bees, and the results do not harmonize with those gained from the apiary. It seems very risky to me, therefore, to draw conclusions from them for normal conditions, since we may easily be deceived. The time of year and the weather, as well as the management of the bees, will greatly modify the results of this kind of experiments. If it is recognized how easily bees are influenced by various stimuli (e. g., shaking, cooling, breathing on them, confinement, feeding, strange strong odors, etc.), I say influenced, diverted, "confused," "subdued," "goaded on," or "calmed," then it will be realized how difficult is the interpretation of such experiments and how cautiously one must work on them.

If one ask Bethe why the unknown force acts at a distance of only three or four kilometers, we receive no explanation from him: he does not even attempt to give one. The explanation, however, is very simple. The mysterious force acts within the space in which the bees have previously taken their flights of orientation, and acts only as far as they have flown at any time and gathered memory pictures. The proofs for this are easy to bring forward. They show on the other hand that this unknown force so designated is identical with memory of location.

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[74] One sees from this that bees pay attention to each other, since they keep together and exhibit the same behavior. Imitation instinct? Sense of hearing?

1. If young bees able to fly (brood-nurses), which have not yet had their flight of orientation, are let fly not far from the apiary, none find their way back to the hive.[75] It is also significant that first swarms, which are almost entirely made up of old bees, in the loss of the queen quickly re-enter the mother colony, while an after-swarm, for the most part composed of young bees, buzzes about for a long time, finally entering strange colonies.

2. If old bees are let fly at a much greater distance they all find their way back.

3. If a colony is brought from a place more than seven kilometers away, and the old bees are let fly only thirty or forty meters from their hive before they have been able to make their flight of orientation, none find their way back into the hive, supposing that (in such a short distance) houses or trees intervene between it and the place from which they were set free.

4. I had two colonies placed in the garden of the Zoological Institute in Jena for the purpose of further investigation. At the end of the summer semester of 1899 they were taken to the apiary of a bee-keeper about two thousand meters distant. Since the colonies were not stupefied, it was presumed that many of the old flight bees would return to the Institute apiary, and, for the refuge of these homeless ones, I placed a hive with some empty frames exactly where their home had stood. Many hundreds returned, which, in spite of complete freedom of flight, loitered around the empty hive uneasily for two days. They were afterward chloroformed, and preserved in formaline, for purposes of demonstration. Their memory of locality had led them back.

Naturally and easily, the varied conduct of bees in these four cases is explained if we accept the theory of an orientation with the eyes through memory pictures, while the unknown force entangles us in contradictions and inextricable mysteries.[76]

It seems remarkable that Bethe attempts throughout to explain "how bees find their way home," but never how they find their way away from the hive. With regard to their finding their way back to a place outside of the hive, he says only the following (Bethe, l. c., p. 90): "The place where a honey supply has been found is again sought, I think, not because of memory of locality, but because of a reaction of the same force unknown to us, etc." Bethe here refers to the observations of Lubbock (l. c.) and Forel[77] who put down vessels containing honey, and observed that marked bees always returned to them.

Because of these assertions, Bethe's theory is still more complicated, and more difficult to understand. We must not conclude, therefore, that "bees follow a force which causes them to return to the place in space from which they flew, which place is generally, but not necessarily, the hive," for in an acceptance of this opinion the bees would have to swing to and fro like a pendulum forced always between their dwelling and the honey supply, whether there is any honey there or not. If they have flown from the hive or from the place where the honey-receptacle was, the unknown force "impels" them to return to both places.[78]

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[75] As is well known, young bees fly for the first time about ten to fourteen days after they emerge. During the first two weeks their existence is that of "house bees," "nurses," who perform all the house-keeping and feed the larvæ. This is, I might say, the firmly established management, from which there is no deviation. Yet we can modify this activity substantially. For example, if we form a colony of bees which have just emerged, and give it a fertile queen, brood, and frames of honey, then we would see that part of the young bees become "field bees" in five or six days, thus taking up the outside work considerably earlier, even if everything is present in the hive, which is necessary for the existence of the colony.

[76] Bethe refers at different times to Fabre's investigations on Chalicodoma (Fabre, Souvenirs entomologiques: Paris, 1879; Fabre, Nouveaux souvenirs entomol.; Paris, 1882.). Yet as early as 1895 Weismann (Weismann, Wie sehen die Insekten? Deutsche Rundschau, 1895, pp. 434-452), had overthrown, in a very interesting paper, Fabre's view concerning the sense of direction. Weismann comes to the following conclusions: "The only correct solution of the enigma of path-finding by Chalicodoma is that the insects find their way back with their eyes."

[77] Morel, Recueil zoologique Suisse, 1 Série, T 4, 1886-88.

[78] If an objection were here to be made, that very probably bees are compelled by the unknown force to return to the place where honey or some stimulus is placed, just as long as the stimulus is present, and that the action of the unknown force could cease with the disappearance of the stimulus, such an exception might appear unauthorized for the following reasons: We should have two entirely different kinds of unknown forces according to this view, since the one leading the bees back to the hive, in fact, forces them to return to the place where the hive stands or no longer stands. Here the stimulus, therefore, is acting in spite of the fact that the means of stimulation have been removed. Then we should have a second force which vanishes with the disappearance of the means of stimulation. Something very different from Bethe's definition, which is not consistent, and decidedly not all conclusive, occurs, for the observation may be made frequently that food or meal remains unnoticed, and is not carried in, if Nature opens stores of honey and pollen (Dathe, l. c., p. 176). Here the bees no longer

THE LOSS OF MEMORY FOR LOCALITY THROUGH SWARM DIZZINESS, ETC.

Through swarm dizziness, as well as through stupefaction (as before mentioned), memory pictures are extinguished, or, at least, are without influence.

If a so-called artificial swarm is made by sweeping the bees from the frames of a strong colony with their queen into a new hive placed upon a new stand, then all the flying bees return to the original hive, and only the young bees remain in the new one with the queen. In a genuine swarm, on the other hand, all the bees remain in the dwelling of their choice. They have forgotten their old dwelling. But it is not a complete forgetting, for, if a swarm becomes queenless within the first few days, then the bees return to the mother colony—the memory for the old home is reawakened. The extinction of the memory for locality is not, therefore, as final as in narcotization, etc. The old nerve-paths are maintained, but are no longer traveled over, because there is a diversion into other nerve-paths; but if the stronger influences are removed by queenlessness (Weiselunruhe, see p. 12), then the old-trodden paths come into effect again and adjust the direction of the stimuli in the former way; i. e., earlier memory pictures are reawakened and the bees return to the mother colony.

An extinction of the memory of locality is brought about likewise by the apparently narcotic influence of buckwheat honey [79] in the cases mentioned before.

Also bees kept in a dark room for many days, and those numbed with cold [80] appear to lose their earlier memory for locality to a certain extent. Further, the throwing of bees into water, the bathing of a colony, will cause the disappearance of the acquired power of orientation.[81] A colony thus handled can be placed in a different position without a return to the accustomed place of flight. Time has a substantial influence upon the disappearance of memory pictures too. In approximately five or six weeks, or often sooner, bees removed to a new position forget the influences of the old place. After this length of time the hive can be changed back and put in any chosen position of the old location without fear of the bees seeking the original spot. Memories disappear quickly if new impressions obliterate the old. If bees stay in a hive, wintering for months, therefore receiving no new place impressions, the impressions which were received before the wintering commenced remain. In very many cases it can be determined certainly whether a transference shortly before the first spring flight can be undertaken without much loss to the colony. If the first weather for flying is inauspicious, as is generally the case, and the temperature scarcely reaches the 7° to 8° C. in the shade necessary for flight, the bees fly out, lingering for only a short flight with slow orientation, and execute the necessary cleaning. They thereby impress upon themselves the new position. But if, as happens now and then, after a long period of cold, a relatively very warm spring day breaks in, the excitement in the hive is great; thousands press forth, and many hasten off for a longer flight with only a hasty, careless orientation. Under such circumstances a greater or less number, in coming back, return to the old place.

Francois Huber [82] reports that in the fall he had fed some honey to great numbers of bees from a window; then the honey was taken away and the hives were kept closed all

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return to the feeding-place, in spite of the fact that food is still present. Very significant for this view is the following account by the well-known writer in apiculture, and editor of the Bienen Zeitung, Wilhelm Vogel: "When I was a boy a beekeeper told my father, under the seal of secrecy, that a colony would swarm in a few days if it were given daily a quart of honey. I immediately placed a dish of honey over my strongest colony during the buckwheat-honey flow. After eight good days of forage the bees had not touched the honey, although it was pure." (Bienen Zeitung, 1880, p. 10.) I might mention, likewise, that the statements of Lubbock and Hermann Muller, about the pretended incapability of bees of not again finding the placed honey will be explained through the mentioned characteristics of bees. The "slight ability" of bees accepted by these investigators is, therefore, not proven through these investigations. In a dearth of honey, on the contrary, the bee is very able to trace out places where extra-floral honey is to be discovered.

[79] If the buckwheat-honey flow is strong, then the bees seem to be unmistakably intoxicated, and they go into the nearest hive-entrance with filled honey-sacs. The observation has been made that hives which are passed over by bees from hives standing further back increase perceptibly in population and honey at the cost of the hives behind" (Bw. Centralblatt, Nr. 3, p. 35, 1894) .

[80] Deutscher Bienenfreund, 35 Jahrg. 1899, Nr. 4.

[81] Francois Huber, l. c. In men, after a violent illness, after a concussion of the brain, after stupefication, after poisoning with carbon dioxide, etc., a loss of memory and retrograde amnesia occurs (Aug. Forel, Das Gedachtnis und seine Abnormitaten, p. 37, ff.; Zurich, 1885; A. Goldscheider, Die Bedeutung der Reize im Lichte der Neuronlehre, p. 28, ff.; Leipzig, 1898).

[82] Nouvelles Observations sur les Abeilles, 2d edition; 2 vol., Paris and Geneva, 1814; German by Kleine, Einbeck, 1856; English editions in 1823 and 1841.

winter. When they were again opened in the spring, the bees came again to the window, in spite of the fact that there was no longer any honey there.

Bethe (l. c., p. 90) asserts as follows: "If bees cease to fly in autumn, then (as I have proven myself) hives may be placed even inside a circle three kilometers in diameter, each in a chosen spot. The bees do not return to the old location of the apiary when they begin to fly in the spring, but from the first come to the hives in their new positions."

This experiment of Bethe's is not conclusive and I would not recommend any investigator or bee-keeper to try it in the way described, for in nearly all cases all the flying bees will be lost.

If, following Bethe's suggestion, a colony is put in a different place in the fall when "the bees have ceased flying" because of the cold weather, one can not tell whether, in spite of the apparent approach of winter, in the next few days or in the first three or four weeks, a warm period with weather suitable for flight may not set in, during which the bees still have the old position securely in memory. If this happens (and it frequently does), then all the flying bees return to the old place and are lost. The next spring, of course, no return to the old locality can take place, for all or nearly all that would recognize the former position are already dead.

ASSOCIATION OF IMPRESSIONS.

During the dearth of honey, when bees are usually excessively fond of sweet things (see p. 26), a few bees discovered a honey-comb in my study, flying through the open window. More and more nibblers came, some of them getting caught at the second closed window. To prevent that, I placed the honey-comb in the opened window itself. When, half an hour later, the bees were flying back and forth I drove them away from the honey and closed the window. After perhaps twenty minutes I went into the bed-chamber above the study, the windows of which stood wide open, and found it full of bees. By this time I was observant, and after driving out the searchers and closing the window I went into the garden and noted their behavior accurately. They attempted in vain to press in at the window where I had fed them, then from time to time some flew to the next window and tried their luck there, then further to the next window above, always keeping about a handbreadth above the window-sill, the height at which the honey had been in the window where they were fed. Thus I noticed bees seeking at all the windows of the house.

If the bees had actually associated impressions and connected the attainment of honey with the form of a window, then it was to be supposed that they would extend their search to the windows of the neighboring house about ten steps to one side, which, in fact, happened.[83]

MEMORY FOR THE FEEDING PLACE IN THE HIVE.

If an inner glass or wire-gauze door is kept closed, the back door of a hive may be opened without the bees getting out. Between these outer and inner doors there is usually enough room to place a feeder. If this is filled with honey or sugar syrup, the bees can reach the food when the slide in the glass door is opened, the outer door being closed. If one is feeding for the first time, the bees may be guided to the honey by placing a few upon it, or in some other way, for otherwise they do not transfer the food as quickly as may be desired, because it takes some time for them to find it. To prevent the excitement caused by feeding, this was done in the evening, and the empty dish taken out the next morning, the slide of the glass door being again closed. But on the next evening, or the one after, I noticed many times that, if I opened the glass door, the inmates streamed out so quickly that I had to hasten to close the outer door in order not to crush any. Also, if the feeding were done in the open air the bees often came hours and days afterward to the place where they had once obtained honey.

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[83] Under the designation, "Instinct or Intelligence," I find in the American Bee Journal, Chicago, 1892, the following note: "If a dish of food is placed on the trunk of a tree, bees will soon search for honey in the same place on all the trees in the neighborhood. A similar thing happens if bees are fed from a window facing south. Soon bees are discovered seeking at the south side of all the neighboring buildings."

It would be difficult to doubt that here we have to do with memory processes; for if bees are reflex machines, following "chemotropically" only adequate mechanical stimuli, then we can not understand why, when the stimulus has not been present for a long time, they react again and again as if the stimulus still existed. A plant never reacts heliotropically or chemotropically to a past stimulus, etc., if the respective stimuli are no longer acting upon it. But here we see movements set loose, although the cause—the honey on the feeding-spot in this case—no longer exists. We see bees once fed, often, after two days, seek that place in vain; but then they modify their procedure; they learn that there is no longer anything to be obtained there, and cease from further flight, often after a few hours, as before mentioned.

CONDUCT OF BEES IN THE BUCKWHEAT SEASON.

If colonies stand in buckwheat, the flight is lively in the mornings until about ten o'clock; then it lessens, and is entirely quiet for the greater part of the day, beginning vigorously again the next morning. The buckwheat honey flows only in early morning; so, as the nectaries dry up, the bees fly out a couple of times and then discontinue their vain flight. In spite of the shimmering sea of flowers, in spite of the strong fragrance, only a few bees may usually be found after ten o'clock in the buckwheat-field.

Here the stimuli of color and scent are constantly present, and there is also the habit of daily flight to the same fields; and, in spite of that, we see that flying is discontinued. Here, undoubtedly, as well as in the preceding feeding experiments described, the processes of learning and remembering may play their important part.

ARE BEES ATTRACTED BY THE COLOR OF FLOWERS OR BY THE NECTAR?

This might be a good place to consider briefly this interesting question. While Plateau [85] substantially advocated the view that bees are attracted chiefly by nectar and not by color, it was above all Aug. Forel [86] who stood almost alone in opposition to this view, based on many years of admirable experimentation. Recently some younger investigators have been associated with him, who can experimentally verify his conviction that it is chiefly the color which serves to attract. Upon the foundation of the work of Forel, Andreae,[87] Giltay,[88] Detto,[89] Kienitz-Gerloff,[90] we can establish as proven the statement that the honeybee, *Apis mellifica* L., is attracted substantially by the color of flowers, and not mainly by the nectar. The color of the flower is indeed a gay flag which proclaims at a distance, "Here there is something to sup."

That bees observe flowers keenly, follows from the fact that single bees in foraging practically never visit two kinds of flowers, but always hold to one kind. This may easily be seen by examining the pollen-sacs on the return of the bees to the hive. One color of pollen is always seen; a mixture of colors, I have observed but once.

PLACE PERCEPTION IN THE QUEEN.

In the literature of apiculture the observations concerning the memory of locality in the queen, so far as the duration of this memory comes into question, diverge very far from each other. Some say that she has capacity for remembering her hive, the outside and surroundings of which she learned to know in her single virgin flight, for more than three years; others say, for some days or weeks. The source of failure in these observations is connected with the frequent unnoticed changes in queens going on unaware of the bee-keeper. He often thinks that he still has the old queen in the hive when she has been replaced for some time by a new one.

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[85] Plateau, Felix, Comment les Fleurs attirent les Insectes. Bull, Acad. roy. d. Belgique, 3 série, T. 30 ,1895; T. 32, 1896; T. 33, 1897; T. 34, 1897, Recherches experimentales sur la vision chez les arthropodes, ibid., 1888, etc.

[86] Forel, Aug., Recueil zoologiques Suisse, 1 série, T. 4, 1886-88 (also as separate); Expériences et remarques critiques sur les sensations les Insectes, partie I.-V.: Munchen (Reinhardt) or Paris (Klingsieck), 1900, 1901; Die psyschischen Fahigkeiten der Ameisen und einiger anderer Insekten, Munchen, 1901.

[87] Andreae, Eugen, Inwiefern werden Insekten durch Farbe und Duft der Blumen angezogen. Beihefte z. Bot. Centralbl., Bd. XV., Heft 3, 1903.

[88] Giltay, E., Ueber die Bedeutung der Krone bei den Bluten and uber das Farbenunterscheidungs vermogen der Insekten, I. Pringh., Jahrb. f. wiss. Bot., 40. 1901.

[89] Detto, Carl, Blutenbiologische Untersuchungen, Theil I. u. II. Flora oder Allg. bot. Zeitung., 94, Bd., Heft 2 u. 3, 1905.

[90] Kienitz-Gerloff, Professor Plateau und die Blumentheorie I. u. II. Biol. Centralbl., 18, 1898, u. 23, 1903.

It is true that queens which fly away from the comb just taken out of the hive usually get lost because they can not find their way home.

I made the following observation: When a queen flew away as just described, I stood perfectly quiet, exactly as I was when she flew, in the hope that, if she had no memory of her hive, she would surely return to the place from which she flew, since bees which have not before oriented themselves always go back to the place from which they flew.[91] After barely a quarter of a minute, in fact, the queen sank down again, not on the comb, to be sure, but upon a little piece of board which lay in the grass a step distant. There I caught her easily and put her back in the colony. In keeping quiet and not changing the surroundings I followed an old bee-keepers' rule, a practice developed from much observation like the above.

But it has, undoubtedly, been established many times by reliable observers that a queen finds her way surely to the entrance of her hive a month after her marriage-flight.

A young queen often errs when the hives stand very close together, if she returns hastily from the marriage-flight. If hives from which flight will take place are marked, therefore, for example with a twig covered with leaves,[92] her return is very much more assured. This is proof that the queen impresses accurately upon herself the appearance of her dwelling.

MEMORY FOR LOCALITY IN SCOUTING BEES.

In the behavior of the so-called scouting bees we find one of the most conclusive proofs against the vague hypothesis of an "unknown force." They prove most emphatically, in my opinion, that an orientation truly takes place through the sense of sight, through memory pictures.

I can not here deny myself the pleasure of inserting the interesting information about scouting bees which Baron v. Berlepsch, the so-called Bee Baron,[93] sent to the Bienenzeitung, VIII., No. 7, 1852.

"Annually, about swarming time one often sees bees in considerable number at holes in the walls and crevices of old buildings, walls, and trees. They creep in and out, apparently seeking something, run anxiously outside and back, flying to and fro. They buzz about as if in front of the hive, and one must have considerable knowledge of bees to be able to distinguish these so-called scouting bees from the true colony. Even if there is no room behind the hole or crevice, I have often seen them forming a cluster before one from six to eight inches long, two or three inches broad, but not at all deep. In so doing they were always uneasy, which does not happen, as is well known, with bees in front of a real hive. These bees are usually regarded as belonging to colonies about to swarm, sent out to find a good place for quarters for the next swarm, hence the name scouting bees or quarter-makers. I see these bees every year at the crevices of the old knight's castle, and in the garden wall and the barn gable. These crevices are often hardly one inch deep, and one-half inch wide, so that there is not room for even the smallest after-swarm. My observation that, although indeed no year passed in which not one but most of my after-swarms escaped, a swarm never alighted here, led me to doubt the common belief; and 1844 I determined to make very exact investigations and experiments, and to take careful note of everything. When, therefore, on May 12th of that year I first saw bees on the edge of the wall, I had them sprinkled thoroughly with chalk toward evening by my usual helpers, and the gardener and I stood in front of the hives to see to which the bees belonged, and whether they were all from one or from more than one hive. Soon coming in, they all entered No. 77 ('Solomon the Magnificent'). Early the next day they were on the wall again, and so it went on for four days. Each evening they were powdered, and their return carefully noted (scouting bees had in the meantime appeared at many other places). They belonged, undoubtedly, to the magnificent Solomon. Finally on the 17th, about ten o'clock, the powerful 'Padishah' swarmed out with a formidable host, went in the direction of the scouting bees, but hung on a dwarf tree hardly

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[91] Orientation begins, therefore, at the moment of the flying out (see Box Experiment, p. 23).

[92] Dathe, Lehrbuch der Bienenzucht, 1892; Bensheim, p. 279.

[93] As is well known, v. Siebold demonstrated Parthenogenesis in bees for the first time upon the estate of v. Berlepsch in 1855 (see Wahre Parthenogenesis bei Schmetterligen und Bienen:" Leipzig, 1856, p. 110 and following).

twenty steps from the hives, fully exposed to the burning sun. I let them hang, and remained standing near. About eleven o'clock they again broke loose, soon alighting in a somewhat shadier place at a short distance, remained there until three o'clock, broke up very quickly for the third time, and went over the garden pavilion toward the open fields. My assistants ran after them. I mounted a horse as quickly as possible, and galloped after them. Before I came up to the assistants the swarm was lost to sight, and we have it yet to see today. The scouting bees were still on the wall, went back again in the evening to No. 77, and appeared early on the 18th. This reappearance was indeed a disappointment, for, powdered on the evening of the 18th, they all entered No. 7 ('Dr. Franzia'), and not one to 'Solomon.' On the 19th, quite early, I had the crevices in all places carefully closed with lime, and put up a straw hive with an alighting-board. The scouting bees came, at first crept behind the hive around the closed crevices, then took possession of the hive. I tilted it frequently to see what the bees were doing inside. I saw little; they ran around anxiously as if they might be cleaning out the hive. On the same day at noon a swarm emerged from 'Franzia' and, after changing its place twice, finally alighted about four o'clock under a shady linden-tree. Here it could be observed comfortably. Single bees flew in all directions, each time mapping out the place with the usual circling flight, then returned; and here the swarm hung over night. With the first shimmer of morning red, there I sat again with my assistants, the garden doors open on all sides as on the previous day, the groom (all the implements for capturing swarms on his back, a true Cupid with arrows) at a short distance with two saddled horses. At 5:30 I saw more bees fly quickly toward the south without circling, and none returned. At 7:30 the swarm broke away again, flying low and very slowly in a southerly direction, and the leaders could be distinguished rather clearly. The groom hastily mounted a horse, and I went running *ipsissimis pedibus* beside the head of the swarm nearly to the end of the garden, ever more and more convinced that the swarm knew where it wished to go. The assistant brought out the other horse. I threw myself upon it, hastened out of the garden, and followed the groom through thick and thin. We followed well at a moderate trot for a quarter of an hour, but finally the swarm went so quickly, always at a height of between four and nine feet, and in a southerly direction, that we had to ride indeed *en carriere.* We came to the next village, not three quarters of an hour's ride distant, and the swarm went into a farmer's garden. I went over the hedge as if in hunt, was in the middle of the swarm with the horse, and then saw it enter a hollow pear-tree. This move took place with such celerity and surety that it seemed to me that the swarm without a doubt had chosen this place in Seebach (through scouting bees). A capture without smoke was not to be thought of, so I begged the owner to let me stay in his Eden for a while (for I would smoke out the swarm for him the very day into a hive, and leave it to him as his property.) After scarcely twenty minutes the bees began to carry out little chips from inside the tree, went foraging, etc.''

Can we explain this interesting procedure only upon the ground of an ''unknown force leading back to the hive''? Can we explain it without accepting the existence of a memory, a capacity for orientation through the eyes, through memory pictures? I think not in the least.

Must we not here acknowledge a means of communication, a method of understanding which does not rest upon odor reflexes? I can not think of this going on without some means of understanding, and I presume that the scouting bees lead the swarm by an alluring sound which naturally can not be observed.

It is noteworthy that, of 60,000 to 80,000 bees, about fifty to a hundred serve as scouting bees; but, peculiarly enough, only before the swarming of the unwieldy, usually low-placed first swarm (often with an old queen heavy with eggs), while the colony never or very seldom sends out scouting bees before the issue of the light-footed after-swarm which with the unfertilized easily flying queen generally alights high up.

Now and then the scouting bees make it very convenient for the bee-keeper by selecting an empty hive and leading the swarm there.[94] Dishonest people who wish to capture

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[91] Deutsche Bienenz. in Theorie u. Praxis, Nr. 9, p. 144, 1899.

swarms not belonging to them put out so-called bait skeps, or hives; and if the scouting bees discover these they often lead the swarm there.

One of the highest colonies ever found (300 feet high) was in the statue of Liberty on the dome of the capitol in Austin, Texas. How high the scouting bees must have flown to discover this strange place,[95] and what power of allurement the explorers must have used to be able to lead the colony to such an unaccustomed height!

THE EYES OF BEES.

Before we turn further to other interesting observations concerning the memory of locality, let us inquire why there are such large well-developed eyes in the three kinds of bees, if orientation through the sense of sight be denied. This is no idle question, for wherever eyes are but little or not at all used, a gradual stunting takes place, etc.; thus, for example, to restrict ourselves to social insects, in the ant, *Solenopsis fugax*, the workers possess eyes with six to nine facets, while the workers of *Apis mellifica* have about 4000 to 5000, the drones about 5500, and the queen about 5000 facets on each eye, besides the three ocelli which are apparently for distinguishing near objects.[96] Bethe has since rejected the statement that the ocelli are probably used for seeing near objects, as incompatible with the "first principles of physiology." I thereupon replied that the renowned physiologist Johann Müller was the first to advance this view, and that observations in natural history confirm and even substantially support it. I have communicated the details in my "Stammesgeschichtlichen Entstehung des Bienenstaates" (pp. 90-95), Leipzig, 1903.

Bethe credits bees with only "a slight capacity for receiving light stimuli" (Bethe, p. 82), basing his view upon an experiment which I on the other hand can not consider convincing. If a large screen be placed in their way, the routine-loving bees will follow the usual path of flight until within 1 to 1½ meters of the obstacle, then suddenly rise and fly over it. But this does not prove conclusively that the bees had not long before seen the immense screen (two and a half meters high and three meters broad). They follow freely the accustomed path as long as possible. Bethe himself says "that a once used correlation of movements may be retained for a long time" (Bethe, p. 92).

In order to experiment to see that bees, instead of being "near-sighted," are very far-sighted, stand at a distance of about ten steps from the hive at the time of the buckwheat bloom, the nectar of which, as already mentioned, excites bees extraordinarily. The bees coming out from the hive-entrance quickly, wholly indifferent as to the direction of the wind, leave painful proof of their ability to see; and a man presents a considerably smaller surface than the screen before mentioned.

"According to our knowledge, everything in living nature has a purpose" (Bethe, p. 19); therefore the very large eyes of bees must be for the purpose of guiding the insect safely and well.[97]

The brain of the bee, very strongly developed in comparison with those of other insects, is certainly not without purpose. The powerful optic lobes (*Lobi optici*) prove unquestionably the great share that the eyes have in the nervous processes.

THE FLIGHT OF ORIENTATION.

How much bees need eyes in flying out from the hive, shows in a very clear way from their striking behavior during the first flight. As the bees fly out they turn their heads toward the hive, and in the continuous hovering up and down (resembling the gnat's dance), the hive itself, the neighboring hives, and the bee-house are surveyed; and, indeed, I repeat it, the head is constantly turned toward the hive, so that even a slight flying backward is shown. This is the so-called first-play (Vorspiel)[98] which is not taken into consideration at all by Bethe, and has not been considered by him as a specially characteristic proof of the orientation by the sense of sight. After this short preliminary flight, small and then larger orientation circles are taken, and thereby the near and distinct surroundings are impressed on the memory.

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[95] American Bee Journal, 1892, Chicago.

[96] Thos. Wm. Cowan, The Honey-bee, its Natural History, Anatomy, and Physiology; London, 1890; German by Gravenhorst; Braunschweig, 1891. a. c.

[97] Up to the present time no one has doubted that the house-fly (about 5000 facets), or the dragon-fly (about 12,000 facets), orients itself during flight solely through the excellently developed eyes.

[98] Dathe, l. c., p. 146.

An old bee flies out from the entrance, if the forage is rich, directly and swift as an arrow. It darts from the entrance through which it has often flown, and knows its path of flight. A young bee flying for the first time must first make a flight of orientation. This is a conclusive proof that bees learn.[99]

THE FINDING OF THE HIVE THROUGH THE SENSES OF SIGHT AND SMELL.

While the sense of sight is sufficient under ordinary circumstances for bees to find their way home, still they use the sense of smell also under the following conditions:

If a colony has been brought from another district, and the slide is opened after the hive is in place, then the bees flying out hasten away without orientation, for naturally they do not know of their change of place, and believe themselves in a well-known neighborhood. In such cases they are seen striking out either in graded flight or mounting in the well-known corkscrew lines without turning the eyes to the hive, as is always done in the described flight of orientation. According to my observation, such bees, flying without first orienting themselves, often come back in a surprisingly short time, because, failing to see the customary landmarks, they immediately begin to seek orientation. If the newly procured colony stand between others which look like it, then in finding their way back there is what Herr Roth, the leader of the bee-keepers' school at Baden, wrote to me "a tasting with the sense of smell, which is extended to the neighboring hives." This is a striking phenomenon easily observed. An orientation with the eyes goes on at the same time, so that the real flight of orientation does not have to be carried on later.

As I have said, such oriented bees that fly out return quickly, often after five or ten minutes, with full burdens if the weather is mild and there is no wind. In cooler weather, and with sharp wind, many go too far into unknown regions and do not find their way back.[100]

Bees remain out on flight seldom longer than one-half hour if the forage is near—almost never over an hour if the forage is distant and in unknown surroundings.[101] They then go home apparently willingly, with a half or a quarter of a full load, as one can easily see in the tiny pollen-sacs and in the slight body.

Let us now hear from Dr. Bethe's description concerning a transported hive (l. c., p, 92). "Lubbock placed some honey out in a room to which some wasps came: he then closed the window which faced the nest. The wasps flew mainly against the window, but finally flew through the other open window. After a few times the greater number flew immediately to the open one. Since, however, a kind of 'accustoming,' based upon an unknown force, seems to enter in finding the way home in this experiment, I hoped to succeed in getting results by observing accurately a new colony of bees. It was bought in a village seven kilometers away, and was placed in the Institute garden about seven o'clock in the morning. At first only a few bees hummed around in the air.[102] A great number sat upon the flight-board and the front wall of the hive, as is generally the case in excited colonies. Between nine and ten o'clock in the morning the first ones flew away.[103]

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[99] The following observation proves how little bees accustomed to the hive's place and surroundings regard the place from which they fly in their swift exit. If the second hive-entrance, which is in the upper honey-chamber (super) is opened for days bees will be seen leaving from this entrance but never entering it. The entering takes place constantly in the usual path through the entrance below. Only by and by bees begin to fly into the upper one (cf. p. 40).

[100] I quote the following from a private letter from Dr. Dzierzon, a distinguished bee-keeper to whom we are indebted for the discovery of parthenogenesis in *Apis mellifica*. Dzierzon died last year 96 years old. "There is not the slightest doubt that bees find their way back to the hive in the way you have described, guided by pictures of their dwelling and the near surroundings gathered as they flew away. Instinct is the explanation in so far as they are led to observe accurately the position of their dwelling and the nearest surroundings in the first flight out. On account of this, as you know, in the first flight, (Vorspiel), they turn around; and, forming small and then larger circles, gain an exact impression of the neighborhood and the hive. I have often wondered at the rapidity with which they are able to do this. I brought a hive from a distant apiary, and on opening the entrance a few bees flew out, probably for water, not suspecting the removal. In the mild weather they were not lost, but came back to the same place, and soon the flying after water was going on as if nothing had happened. Thus quickly a part of the bees had become accustomed to flying in the new apiary," etc. Even though this letter contains no new knowledge of the biology of the bee, yet it seems to me that its publication is appropriate, in view of Bethe's opinions following.

[101] As was mentioned before (see p. 19), the leader of the bee-keepers' school at Baden observed that his bees returned from a buckwheat-field six kilometers away, with full burdens, on the average in thirty minutes.

[102] It is a pity that we can not learn how these bees acted, whether they oriented themselves, etc.

[103] Accordingly this appears to have been a cool autumn or spring day, else it is inexplicable why the bees hesitated so long with their flying-out. Or was it windy or rainy weather? Or were the bees wearied with the transportation?

They corkscrewed in widening circles into the air, as bees do when they have just been set out. After three or four circles (in which note well they had never turned their eyes toward the hive),[104] they took their direction and flew quickly to the meadows. A great number of others followed, all corkscrewing into the air.[105] About three o'clock the first ones returned laden with honey and pollen.[106] They came from the east (not from the south whither most had gone), and flew from the place where I first caught sight of them (5-6 meter distant) in a *straight* line to the entrance. If here a noticeable accustoming had played a part, perhaps as a memory process, it would be impossible to think that the insects would fly in such a straight line for the hive. A force then must be present, which draws them like a magnet to this place in space, and the described 'accustoming' is something secondary, unnecessary for the occurrence of the reaction.''

Since we have not the slightest scientific proof whether these bees which returned at three o'clock, which ''flew in a straight line to the hive,'' did not belong to those which had hummed around the hive in the early morning, and therefore had been able to notice the position of the dwelling accurately, this experiment proves nothing, because we are not informed concerning the method of the flying-out of the later bees.

Bethe speaks expressly of ''accurate observations,'' so we must accept as a matter of course that there were no errors in his observations. If, therefore, the foregoing really happened as pictured, this experiment does not, I believe, present a conclusive proof for but against the ''unknown force.'' According to my long years of experience, a five or six hours' roving and remaining away from the hive under the conditions described is entirely impossible. We may here, from what is known of the natural history of the bee in this direction, count upon the possibilities expressed before. Later on it turned out that the observation was not an accurate one. Cf. p. 90 of my Stammesgeschichtliche Entstehung des Bienenstaates. Leipzig, 1903.

If, indeed, a magnetic force existed to draw bees homeward, then without doubt the bees which flew out would have succeeded in reaching home inside of ten minutes or at most an hour after leaving.

BETHE'S TREE EXPERIMENT.

This is the place, perhaps, in which to examine more closely Bethe's tree experiment. ''In the fall of 1896 I put my hives in a small house which lay toward the east. In front was a plane-tree, seven meters high, whose branches approached the house within about one and a half meters. The top of the tree was eight meters wide and began three meters above the ground, so that the little bee-house was completely shaded. Now, because the bees flew very badly in the spring of 1897 on account of a lack of sun, I decided to have the tree cut down, and this was done in the morning about 10:30 (June 11, 1897), just when most of the bees were out. Thereby were the surroundings of the little house completely changed: instead of the high tree there was a large open quadrangle fifteen meters square. The bees had been coming perpendicularly between the tree and the house to their hives, but those returning (which had flown out long before the change, since they all had pollen on their legs) immediately after the fall of the tree flew directly in a slanting line to the entrance. They flew, therefore, through the space in which the tree had stood a second before, and showed not the slightest uneasiness; they were not 'surprised,' as, without doubt, many authors would report with astonishment'' (Bethe, p. 85).

Bethe decides from this that finding the way home can not depend upon memory pictures.

From this statement of Bethe's we get the idea that there were no obstacles present but the plane-tree. Up to where the branches began, therefore, there was a free path three meters high. No one who is familiar with the practices of bees will doubt that the

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[104] Bethe appears to consider this the normal flight out; above all, nowhere does he mention the entirely different flight of orientation.

[105] As none of these bees flew off in a straight line, it is natural to suppose that these were greatly irritated by the transportation or suffered by the lack of air during the transportation. The thick gathering on the outside points to the latter supposition, as does also the late flying-out.

[106] Therefore after five or six hours! Doubtless almost all the bees which flew in the forenoon were lost, or returned again to the known neighborhood, because the village was only seven kilometers distant, for under the conditions cited an absence of five or six hours can not be accepted as true.

bees used this large space for flying, therefore flew under the branches. A bee always flies low to the forage unless obstacles are present or the distances are extraordinary; and there is not the slightest discernible reason why the bees should not have used this comfortable path if they flew mainly in the direction of the tree. It would have been abnormal if they had not done so. That Bethe noticed the bees flying in under the branches or through the top of the tree only after the tree was down is easily explained, since their flight was much more visible, and the tree had not been cut down for the sake of observations but merely to remove the shade. The opinion might, therefore, be allowed that the special kind of flying in had not before been accurately noticed. That bees fly through bushes standing not very close together, or through trees which put out their leaves late (as does the plane-tree), I have often observed. They maintain the accustomed flight as long as possible. But there is no contradiction in saying that bees, and perhaps very many of them, came down "perpendicularly between the tree and the house to the hive." But they surely did not fly out over the tree, but to the other side over the roof of the "little house," or sidewise over the roof to the "meadows" lying in the "south." I am strengthened in this opinion by the following assertions of Bethe: "I have said that the bees returning after I had cut down the plane-tree in front of the apiary, flew immediately through the place where it had stood instead of, as before, coming down perpendicularly in corkscrew lines. The outgoing bees conducted themselves in an entirely different way. After the fall of the tree they corkscrewed upward penpendicularly just as if the tree still stood. When I saw the bees fly for the last time in this year (it was on September 14, therefore about three months after the tree had fallen, June 14), all the outgoing bees still flew upward perpendicularly in front of the house, as if the tree still stood. I am wondering what they will do next year. There can be here no question of any perceptions of the senses, of any deliberations" (Bethe p. 92).

Bethe here overlooks the fact that most likely all the bees which flew September 14th had never seen the tree, since in summer bees live at most six or seven weeks.[107] The cause of this singular flight was, therefore, certainly not the tree which fell fourteen weeks before. There can, therefore, be no question in this case of "perceptions of the senses," as Bethe says with another significance. And then "the next year"!

Even if the foregoing observations are accurate, it is clear that the peculiar flight of the bees has not been necessarily because of the tree, and therefore the demonstrative power of these observations is very doubtful.

Exact judgment is not possible in this case, since the other obstacles further away perhaps, as there undoubtedly were, are not mentioned.

I made the following control experiment: Close to my hexagonal bee-pavilion garden-paths strike out to the east and southwest. In order that passers-by would not be troubled by the bees, I was forced to plant bushes and trees so thickly in front, one-half to one and a half meters, that the bees were compelled to fly high immediately. The majority did me this kindness; but those which developed early in the spring, before the leaves came out, picked out larger or smaller openings between the twigs or between the bushes as pathways, and held to these paths even when the space became almost entirely covered with leaves. Because of a birth-tree standing on the southwest side, six meters high and about two meters wide, the lowest branches beginning only about a meter from the ground (therefore a rather bush-like growth), the flying bees from a colony standing a meter and a half away, and over one meter high, were forced to divide. Some of them flew to the left, others to the right, since the young trees standing next had not yet effected a closing. The birch was cut down, and I noticed as follows: No hesitation of

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[107] "How great the death-rate is, especially at the time of forage, the following experiments prove: I made several artificial swarms from pure German bees, with a pure Italian queen. In six weeks there was not a single German bee left. July 17th I took a rather old German queen from a hive and put in an Italian the third day after. Notwithstanding the fact that for three weeks the German brood emerged, after six weeks, scarcely every twentieth bee was German."—Dzierzon in Bienenzeitung, IX., No. 23. "The length of life of workers is usually very short. Those reared in the spring and summer live often hardly six to eight weeks."—Ludw. Huber, Die neue, nutzlichste Bienenzucht, 13. Aufl., Lahr, 1900, p. 16. In rich forage the bees live often only two or three weeks. Many personal observations sustain the foregoing. Queens usually reach the age of four or five years; but cases have been known of queens which were six or seven years old (Bienenzeitung, 1882, p. 78).

the bees in any way remarkable took place, as regularly happens if the surroundings of the hive itself are changed. The explanation, I think, lies in the fact that the bees in flying out undertook no special inspection of the surroundings—they know their own circle of flight.[108] The in-flying bees could adjust themselves by so many other landmarks, all of which are still present in the immediate neighborhood of the hive, that they were not confused by the absence of one landmark in the proximity of the hive, since by that time the hive itself was recognized.

The flight itself remained forked for many days. Some few, however, a few minutes after the fall of the tree, went out through the space where it had been. As the colony was very weak, and usually only a few bees were seen under way, I can not say whether these bees had before flown through the spaces between twigs, for an hour passed before I saw another fly through the now open space. These few which flew through might easily have been overlooked by me before.

But even if all the bees had suddenly flown out in a straight line, I could see in that no confirmation of an unknown force, with so many proofs against it, but only a special capacity for orientation.

SPECIAL CAPACITY FOR ORIENTATION IN BEES.

That bees orient themselves indeed in a special way follows from many things. Lubbock[109] also is of this opinion. Nevertheless in general one is inclined to apply human standards to them. A simple experiment shows that bees have their special estimation of position.

If the height of a hive is changed so that the entrance is suddenly made, let us say, thirty centimeters higher or lower, then we see that the bees fly exactly to the spot where the entrance was before. Hours and often days pass before a smooth graded flight is to be noticed to the new height. To my mind it follows from this that in fact, as Lubbock also believes, the bees "know how to find their way by the relative position of the well-known entrance to the surrounding trees and other large obstacles, and to the hive itself." The principal thing is the relative position of the entrance to the ground, for trees and large obstacles can be lacking and yet the entrance be reached, for the bee has an extremely fine ability for the appreciation of height. The entrance itself is not regarded at greater or less distances, as the experiment given above proves, for first an observation of it takes place in the immediate proximity. This ability to judge distances goes so far that, under normal conditions, bees are accustomed to fly, for example, always in and out of the same corner of the hive-entrance. If a bee is powdered on entering at the outermost right corner of the entrance, it will be seen that, in unmolested flight, it uses the same corner constantly in a straight line, even if the entrance is only ten centimeters wide. If the entrance is then stopped up all but about the breadth of an inch, they will, in spite of that, try to press in just at their points, and find the open part only after a shorter or longer search.

This accurate adherence to a settled path of flight has something to do with the relative position of the hive or the entrance, but not with the hive itself nor the entrance itself at all; for if the hive is taken away entirely the bees will continue to fly to the accustomed place at the accustomed height. In such steadfast holding to the path, all disguises such as Bethe's have little proving value (Bethe, p. 85), in so far as (and Bethe leads on in part to this end) it should prove that bees are guided on their way, not by memory pictures. The simple consideration that bees fly back exactly to the place where the entrance has been, even though the hive has been removed many days before, makes it clear that their flight will not necessarily be led astray if the hive or background be completely disguised, as was done by Bethe; therefore the spreading of colored papers on

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[108] The careless flying-out of the bees, which is often fatal, is well known to the bee-keeper. On this is based the old practice that colonies which are to be sent to buckwheat-fields are always brought out to these fields before the buckwheat blooms, so that the bees can learn thoroughly the new locality. If the bee-keeper does not stick to this rule the proximity of the strongly fragrant fields is so stimulating that the bees pour out without any orientation, or only a hasty one, and then they get lost, etc. The colonies fly themselves "bald" (cf. p. 32).

[109] Lubbock, The Senses, Instincts, and Intelligence of Animals; London, 1889; German translation, Leipzig, 1889.

the ground in front of the hive can not, of course, influence the valuation of the height particularly. If it is wished to draw the conclusion from this that bees are not led on their paths through memory pictures, that seems to me to be anthropomorphism of the best kind.[110]

It is no contradiction to this that bees notice very closely the appearance and form of the hive, as I have said before. One needs only to fasten a piece of colored paper above the entrance or to change the form of the hive to notice immediately a hesitation in the flight toward it; a closer survey is taken while flying in.

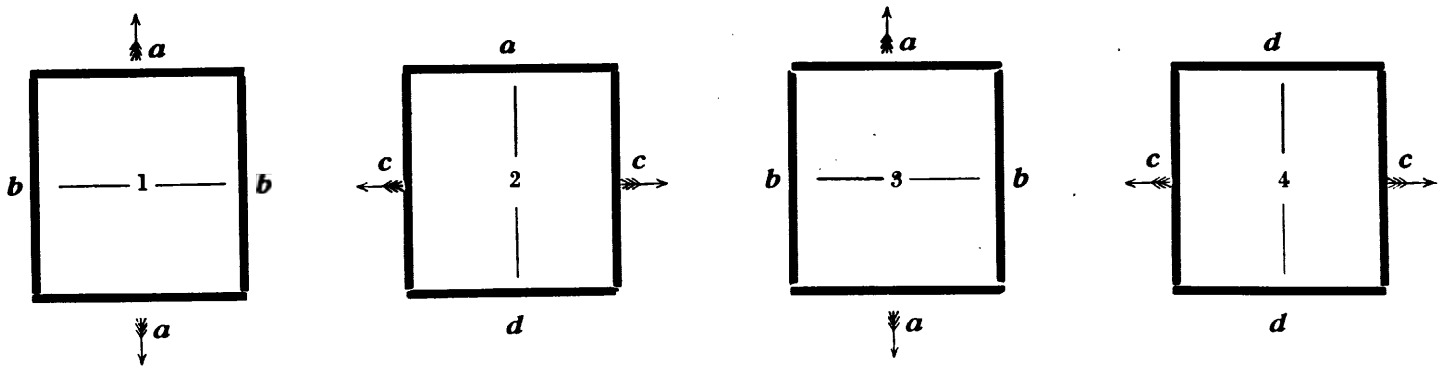
A bee, therefore, flies to the point of the entrance without being able to see it or the nearest surroundings of the entrance, on the basis of its orientation in their neighborhood; on the other hand, when it comes closer it generally notices the surroundings of the entrance, for it becomes aware of any changes in the outside of the hive. The quicker it hurries back to the hive (for example in a heavy honey-flow), the less the appearance of the hive is noticed; and if attention is gained by a very striking change, the hesitation or loitering to be seen is much less.

THE INFLUENCE OF WEATHER CONDITIONS ON THE SENSE OF SIGHT, THEREFORE ON THE ABILITY TO ORIENT.

If bees are thrown up into the air at dusk, not far from their dwelling, they do not find their way back. They make several small circles and then fall to the ground, "frightened and lost." Bethe has made this experiment, but we are not told why the "unknown force" does not act under such conditions. That simply the sense of sight is here determinative in regard to orientation may be clear from the following observations:

"A fruit-grower in England was astonished to find the trees much more heavily laden with fruit in the part of his large garden where there were some colonies of bees than in the other parts. He then remembered that it was extremely foggy during the blooming of the fruit-trees, and the bees, in consequence, flew only short distances."[111] Any one who has observed bees for a long time knows how strongly sudden dark clouds influence flight. In such cases we often see an amusing sight during the honey-flow. At the approach of a storm the hundreds of thousands of bees that have hastened to the fields, rush in wild haste to their sheltering homes. With pollen-sacs hardly begun to be filled they stream on in blind haste in a ceaseless train and "dash" into the hives. If it happens that the clouds are in the background, and the sun is shining on the thousands of whirring wings, the appearance is most peculiar.

That we have to do with orientation through the eyes in this journey home at the approach of a storm, and not with an "unknown force," follows from the fact that, in the



"mad haste" mentioned, many blunders are made, and many bees enter strange hives. An "unknown force" which "draws like a magnet" would not permit such errors.

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[110] American bee-hunters base their methods of capture on the above-mentioned fact, that, if bees have once flown in, they regulate their paths of flight with extraordinary accuracy, and constantly fly in almost a straight line. "In a clearing of the woods a little fire is made and an old comb held over it. Attracted by the odor, bees come and taste the honey inside. After sufficient orientation they begin by degrees to take up a straight line of flight. The hunter follows this line and marks it with any landmarks at all. Now the bait is placed at the other end of the clearing. After a short time the bees find it again, and the line of flight is again marked. Then, where the two lines cross, the colony is found. Autumn is most favorable for this, for since then no other forage attracts the bees and leads the hunter into error."—American Bee Journal, Chicago, 1893.

The bee-keeper also uses this characteristic of bees to discover a robbing colony. "The bees always fly in a straight line from the place where they find food, back to the hive. The bee-keeper, therefore, goes in this direction and soon stands before the hive where the robbers belong."—Ludw. Huber, l. c., p. 35, 1900.

[111] Bienenwirtschaftl. Centralblatt, 1892, Hannover, p. 205.

A very important bee-keeper, Herr Dathe, in Eystrup, submits the following: In his extensive apiary of about five hundred colonies there were various stands of box hives. The line of flight went on as indicated in the figure above in various directions. The arrows give the point of the entrances—that is, the direction of the flight in and out.

Just before thunderstorms, etc., Dathe made numerous observations, that in their hasty return many bees threw themselves on the wrong stand; and such as were accustomed to enter at the side (c) made great exertions in vain to get into the hive at the stands 1 and 3 at the corresponding place (b), although there was no entrance there. In the same way the "a" bees sought their hive-entrance on the stands 2 and 4 at "d."

A similar thing is seen in a violent wind, which throws the bees out of their accustomed paths of flight.

It follows from this that a memory picture of the hive is present, as well as a valuation of the right place and height, even if on the wrong stand. An explanation of this error is, I might say, natural as soon as one ascribes the orientation to the sense of sight. It is difficult to think of it on the ground of the unknown force.

I owe further interesting observations to the already mentioned leader of the Baden Bee-keepers' School, Herr Roth. This leads us at the same time to the special reaction of bees toward colors.

INFLUENCE OF COLORS ON BEES.

I shall here mention only two observations, and for the rest, in regard to the influence of color on bees, I can only allude to the well-known experiments of Lubbock[112] and Hermann Müller,[113] as well as to those of Bethe (l. c.), etc.

We have seen above that flight becomes very unsafe in the dusk; therefore it is evident that gloomy weather influences considerably the ability to orient.[114]

"One of my former neighbors," says Roth's contribution, "painted the gable of his house over the apiary with sky-blue (luftblau) color. The very bees which always flew over the gable, on the next dark day bumped against it with their heads, trying to fly through it."

A teacher, Stahelin, made the following observations: A weak after-swarm, mostly of young bees from a hive painted blue, dispersed[115] among the masses of humming bees which were just taking their flight of orientation out of the other hives (which, as is usually the case in Germany, Switzerland, and Austria, were standing close together), and settled here and there in little clumps. After a short time they flew back to the bee-house; but only a few found the right hive; the rest flew to other colonies, and to which? Only where a blue door invited them did they attempt an entrance, but nowhere else. Unfortunately they were so hostilely received that the ground in front of all hives marked blue was covered with dead bees.[116]

These cases also show nothing of an "unknown force," but, instead, exhibit the great significance to bees of the sense of sight, and the errors suffered through deceptions of the eyes.

The disproof of Bethe's theory by Forel appeared independently shortly after the publication of my paper (Forel, Aug., Sensations des Insectes, IV., Paris, 1901). Forel reaches the same conclusions that I do (cf., also, Forel, Aug., Nochmals Herr Dr. Bethe und die Insekten-Psychologie, Biol. Centralbl., Bd. XXIII., 1903). The confirmation of my work by this important investigator is of special value to me. The quintessence of Forel's views about all these matters will be found in his paper: Die psychischen Fahigkeiten der Ameisen und einiger anderer Insekten, München, 1901, which has been translated by Wm. M. Wheeler: Ants and some other insects. An inquiry into the psychic powers of these Animals with an appendix on the peculiarities of their olfactory sense. Chicago, 1904.

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[112] Lubbock, Ants, Bees, and Wasps. International Scientific Series: New York, 1883; German translation, Leipzig, 1883.

[113] Herm. Muller, l. c.

[114] The similar behavior of carrier pigeons may be compared with this (H. E. Ziegler, Ueber die Geschwindigkeit der Brieftauben, l. c.).

[115] Because the swarm tone which holds the swarming bees together (see p. 16) had been swallowed up by the loud buzzing of the other colonies which were giving out many bees in their "first play." This shows the possibility of communication through hearing!

[116] Schweiz. Bien. Ztg., Aarau. Jahrg. 1893.

In my "Stammesgeschichtlichen Entstehung der Bienenstaates" (Leipsig, 1903), I have, in Appendix 4 pp. 90-95), a "concluding word concerning Bethe's investigations on bees. The significance of ocelli in bees," in which I confirm my views on their ability to see, and verify it in part through experiment. Many other pertinent questions are there touched upon.

Full of importance in consideration of the ability of insects to orient by their eyes is the following work of the Peckhams. The observations of the Peckhams on the sense of orientation in wasps supports my work on bees. Unfortunately this entire excellent investigation (On the Instincts and Habits of the Solitary Wasps, by George W. Peckham and Elizabeth G. Peckham, Madison, Wis., 1898), became known to me only after a long time after the German edition of this paper had been published. I value these observations more highly than the very admirable but frequently visionary work of T. H. Fabre (Souvenirs entomologiques, Série 1-9. Paris, 1879-1905).

The works of Bouvier on solitary wasps (Les Habitudes des Bembex, Monographie Biologique, Paris, 1901); of K. Escherich (Die Ameise, Braunschweig, 1906), and the observations of Charles Ferton (Notes sur l'instincts des Hyménopteres, Melliferes, et Ravisseurs, 3 série, Paris, 1905, fall in this province. All these works give many beautiful explanations, and confirm my statements more or less.

SOME FURTHER CONTRIBUTIONS TO THE NATURAL HISTORY.

THE FLIGHT OF BEES INTO A ROOM.

If honey is placed in the part of a room opposite the windows, and the windows opened, bees will soon appear at the openings. The flying-in is accomplished in a very characteristic way. Very slowly, as if cautiously exploring, they risk going into the inner part of the room where the light is subdued. Timidly the advance is made, back and forth; here and there goes their flight until the honey is reached.

When I was occupied with investigations on bees' eggs one summer, some honey-comb was standing in the laboratory of the Institute. One day, on opening the window, some bees flew in with remarkably certain flight to the wall opposite the windows. That puzzled me, and I called the matter to the attention of the assistant, Dr. L. Schultze, who was present, with the remark that these bees must have been nibbling sweets in another room, because their flight was so sure. The only honey in the Institute was in the room of the assistant, and that window proved to have been closed. I knew from their coloring that these were strange bees, not those from the apiary in the Institute garden. The enigma was soon solved. In a villa, scarcely twenty steps away from the open window, a bee-keeper had a couple of colonies on the loft under the roof. The bees flew through the roof window, and were, therefore, accustomed to flying into a dimly lighted room.

This modified conduct proved to me that bees undoubtedly learn. The bees from an outdoor apiary would certainly have acted differently.

THE BEHAVIOR OF ROBBING BEES.

Robbing bees look like robbers very soon, for they soon lose the hairy covering, because, with their foreign hive-odors, they are pulled and hauled about when they force themselves into strange colonies, and also because energetic licking must be done, as they get soiled with honey. The colored hairs disappear, and the dark hard chitin shows, as can be seen in the spring on old bees too, which have lived over the winter.[117] In summer, when most of the bees are not old (see p. 35), robbers can be recognized in most cases by this appearance.

Since the loss of hairs on bees gives them the appearance of being smaller, these "black bees" were formerly taken for a special kind of bee. [118]

It is of special interest to watch the conduct of these robbing bees, for they depart completely from the usual behavior of workers.

Their flight to a strange hive, when they are just starting in their profession, is very uncertain, "timid," and "anxious." [119] Even the boldest act as if they did not dare to follow their desire to rob, as if they knew the danger in which they were placing themselves. But if they once succeed in entering a hive they soon become bolder, and "those which have carried on robbing for a long time may be recognized by their hasty practiced manner of entering." [120] Here, again, we have a beautiful example of capacity for learning.[121]

THE ORIGIN OF HOSTILE CONDUCT.

While solitary bees, such as *Chalicodoma muraria* or *Andrena ovina* or *Anthrophora personata* have apparently no knowledge of their enemies, we see in *Apis mellifica* that this

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[117] Dathe, l. c., p. 180.

[118] Bienenzeitung, No. 5 and No. 11, I.: Nos. 13, 14, 15, V.: further, Dr. Magerstedt, Der praktische Bienenvater, 2. Aufl., p. 154: Sondershausen, 1845, etc.

[119] Lud. Huber, Neue nutzl. Bienenzucht, 13. Aufl., Lahr, 1900.

[120] Dathe, Lehrbuch der Bienenzucht, l. c., p. 180.

[121] "The nibblers are often so bold that they stop the bees coming from the field at the entrance, and the latter, therefore, getting the idea that they have flown into the wrong hive, reach them their probosces and thus let them steal the honey from the mouths. Such robbers are like swindlers in a great city, who cloak themselves as police officers, and under this mask carry out their fraud." Dathe, l. c., p. 183.

species understands how to make its enemies for the most part harmless in the hive. Carriere[122] thinks that this knowledge and ability to exterminate them is formed in *Apis mellifica* because it represents "a permanent community, and therefore a 'tradition' could have been developed." I can not share his opinion, which supposes entirely too much human intelligence. I believe that here the principle of selection has acted also. For colonies which collect a supply of honey it is naturally of great significance that there should be means of defense against the entrance of robbers, etc. Therefore the instinct developed, by and by, to react hostilely toward those entering with a foreign hive odor or with unusual behavior.

THE VANISHING OF INSTINCTS WITH THE DECREASE IN THE STRENGTH OF A COLONY.

Only a strong colony resists its enemies, such as robbers, wax-moths, etc.—not that the weaker colony is not able to do so very well, for there are still plenty of fighters, but it is a fact that its "spirit," its "energy," disappears as a colony weakens. The narrow entrance could be defended with ease; but such colonies often do not place bees at the entrance at all. They let single robbers and single wax-moths, etc., quietly alone, although they could kill them with no trouble.

The more reduced a colony becomes, the more do all instincts fail. The hive is no longer cleaned, flights are more and more discontinued. Languidly and "apathetically" the bees sit around on the comb. If, finally, almost all are taken away, so that only the queen remains with a handful of bees, even honey which has been placed in the hive remains untouched.[123]

In experimental observations, particular attention should be given to this characteristic failure or weakening of instincts with the decreasing strength of a colony, for otherwise the results obtained are never exact. A weak colony acts entirely differently from a strong one, and the reactions are often in the opposite direction; also the varieties of *Apis mellifica* must be taken into consideration, as a small colony of heather bees of North Germany, for example, acts differently from a weak colony of bees from middle or southern Germany, and these, again, differently from Carniolan or Italian bees under the same circumstances. In short, one must be entirely familiar with all the factors pertaining thereto in order to obtain results free from error.

REACTIONS TOWARD FLIGHT.

We must certainly notice further a reaction of bees which thus far has been thought to be slight, but the disregard of which can lead to false conclusions; that is, the sharp reaction toward the manner and way of flying to the entrance of the hive. In many cases, therefore, it may not be the special odor which betrays the robbers, but as said, their "timid" loitering flight. The bees which defend the entrance and flight-board may often be seen to baffle the attempts of robbing companions by flying at them and seizing them in the air before there can be, in my opinion, the least perception of the odor of these single bees, because of the strong evaporation from the hive entrance.[124] It is a reaction toward the special kind of flight. In connection with this is this fact: that if the robbers are more cunning, and go flying smoothly into the entrance, a defense is hardly noticeable, and often does not take place at all.

If the experiment is made of bathing bees in water or weak alcohol to remove the adherent hive-odor, and, after drying, the bees are allowed to run into their hive, they can enter the accustomed opening safely on account of their quiet and sure manner of entering, and no definite reaction of the inmates is noticeable. If the bath is thorough, there will be no definite reaction set free when entering a strange hive either, not only because the foreign odor is taken away, but also because the bath destroys former mem-

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[122] Carriere and Burger, Entwicklungsgeschichte der Mauerbiene. Abhd. der Kaiserl. Leop. Carol. deutsch. Akad. der Naturf. Bd. LXIX., No. 2.

[123] And yet, as is well known, the attraction of honey for bees surpasses everything else. If the abdomen is quickly severed from the thorax while a bee is sucking on a drop of honey, it sucks on quietly for a long time, while the sucked-up portion flows out behind.

[124] I spoke before (see p. 14) of how little bees are able in open air to perceive the strong odor of the queen at approximately short distances.

ories (see p. 27),[125] and the respective bees no longer know their own hives; so without hesitation they run in, and their quiet entrance is often little or not at all noticed.

If a queenless colony is allowed to run into a queen-right one, or if it wanders over of itself, a broad stream of bees joyfully "humming" enters the strange hive. These usurpers of the strange dwelling, with such a sure (and I might say matter-of-course) manner must in most cases have a somewhat "disconcerting" and "embarrassing" effect on the inmates, for seldom is a defense attempted. It appears, therefore, that the hive-odor is not the only absolutely certain sign of recognition, but that the kind of flight, the particular conduct on flying in, plays an important part in the recognition of friend or foe, or at all events in the setting free of hostile reactions.

If daubed bees, which have, in addition to the foreign hive-odor, a still stronger odor of the substance used in daubing, are shaken on to a colony, hostile reactions are never set free, for the bees shaken on lie entirely quiet or move only very slowly.

THE FORMATION OF THE CELLS IN THE COMB.

The honey-comb, apparently so "ingenious," can hardly be brought in as proof of the higher faculties of bees, since it is only the result of mechanical force, as Müllenhoff[126] demonstrated, and as is well known. I can not reconcile myself to many statements in Müllenhoff's explanation, for they do not entirely coincide with my observations. But a doubt can scarcely be raised against the foundation of Müllenhoff's theory of the mechanical acting principle. According to his theory, a so-called one-sided comb can not produce the pyramidal cell-floors formed of three rhombs, yet we see them frequently in such comb. Also the case can not be so represented as tho bees worked with semi-liquid material in order to explain thereby the tension of Plateau's "liquid membrane," or the tension of the floors and sides of the cells. In a cluster of bees the temperature is usually from 28 to 34° C., while the melting-point of wax is 62° C. Of course, the wax at 30° is weak and easily molded, yet there remains for the instinctive activities of bees the act of thinning and smoothing of the floor and walls, as independent productions, as well as the special sizes of cells. Mechanics does not explain why drone-cells are so much larger than worker cells, but the form and the width of the angles have certainly nothing to do with the "dexterity" of the bees. I can here only refer to the interesting work carried on.

Müllenhoff's statement that, in the cells thus formed, a "drop of the secretion from the poison-gland" is added for the preservation of honey "gathered not for immediate use," is anthropomorphically quite clear, but does not correspond with the facts in the case.

This statement has been proven untenable by Schonfeld[127] and by Planta[128] through chemical analysis. I must also call into question Müllenhoff's view that "the form of the body of the animal depends chiefly upon the form of the cell in which it developed" (l. c., p. 616). For the purpose of other observations I placed a colony only upon drone comb, so that only the large drone-cells were available for the queen. After long hesitation she began to lay eggs. From the drone-cells, besides a number of drones, mostly workers of normal size crept out. The nourishment does not here come into consideration, for in all cases that was as usual. Drones also which have hatched in queen-cells are very frequently of normal size. The view is not correct, that the cell "surrounds the entire body of the insect like an enclosing caoutchouc sheath, hermetically sealed, and, accordingly, it must be the cell which determines the form which the body of the young developing insect shall assume." The larva has room for motion, else it would not be in condition to spin its cocoon in there.

That drones are smaller if reared in worker-cells is not positive proof of Müllenhoff's theory. These are, I might say, necessary relations, and do not permit the conclusion that we "get a suggestion concerning the *causa efficiens*, which may change the body-form of the insect from the action of the molecules of the cell constituents." If bees go over to the building of drone comb, which condition is noticed regretfully by bee-keepers, because then

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[125] I must mention the fact that memory pictures are not always effaced by bathing. It seems that the length of time and the temperature of the water are particularly determinative. My experiments in this direction are not yet concluded.

[126] K. Mullenhoff, Ueber die Entstehung der Bienenzellen, Pfluger's Archiv f. d. ges. Physiologie., Bd. XXXII., Bonn, 1883.

[127] Gravenhorst's illust. Bienenzeiting, Nr. 5 u. 6. Aarau, 1893

[128] Schweizerische Bienenzeitung, Nr. 5 u. 6, Aarau, 1892.

only consumers and not producers are reared, artificial foundation with the floors of worker-cells pressed in may be hung in the hive. The instinct is thereby diverted, and the bees erect worker-cells according to the wishes of the bee-keeper. In the hope of increasing the size, and at the same time the capacity for production in workers, colonies have been placed on foundation on which had been impressed cell-bottoms in size between those of workers and drones. The bees built cells corresponding in size on this; but in spite of the extra room for the developing brood the size of the workers remained exactly the same.

THE PLAY INSTINCT IN BEES.

Although I am decidedly of the opinion that there is to be noticed in the gay circling of swarming bees at the same time the activity of certain play instincts, still proof is certainly difficult, inasmuch as all the proceedings which come into consideration may be led back exclusively to the swarming instinct, and can be explained only as an expression of that instinct. After all, this strong pressing-forth from the entrance, this sounding of the "joyful" clear swarm-tone, which (as already mentioned) drags into the confusion colonies nearly ready to swarm, these waves up and down in the sunshine in "drunken lust" (swarm-dizziness), all exhibit the playing activity of a certain surplus energy, and therewith one of the fundamental elements of play. Schiller, as well as Herbert Spencer, sees in play the expression solely of overflowing energy. I refer, therefore, to the ingenious and interesting work of Karl Groos,[129] who, correctly, does not find complete satisfaction in this interpretation, and who alludes to the great biological significance of the instincts which are early manifested in play, and which perfect themselves in play. Groos does not mention bees in his very comprehensive work, and yet we may mention, besides the swarm-dance, where the play character may be doubted, a singular activity of bees, which, in my opinion, shows undoubtedly true playing. Especially on warm summer evenings, but at other times also, now and then on the outer walls of hives which are in good condition, near the entrance or on the flight-board rows of bees may be seen moving to and fro in a peculiar rhythmic way. As the head is held down it looks as if the ground were being gnawed or licked in rhythm; but nothing of this kind takes place. A very characteristic "contented" humming is audible. We doubtless have here in play the expression of a feeling of comfort.

Single bees are often seen not fitting into the common rhythm of the line, but I have frequently noticed a gradual adaptation to the prevailing manner. It seems that there must be a special pleasurable sensation in this common rhythmic movement or else it itself and the apparent mutual adaptation would not take place.

The whole interesting phenomenon seems to me clear, if we accept the idea of the expression of a play instinct. It is known to every experienced bee-keeper generally under the name of swinging or planing (Hobeln).[130]

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[129] Karl Groos, Die Spiele der Tiere, Jena, 1896. (2. Aufl. 1907.)
[130] Schmid und Kleine, Leitfaden einer Ration. Bienenzucht, Nordlinger, 1865, etc.

CONCLUSION.

From the very rich material which the natural history of the honey-bee affords I have been able to take into consideration in the foregoing pages only a few essentials. But these may have shown us, I hope, that it is superfluous to suppose in bees the presence of an "unknown force," since the biological proceedings are made clear easily and naturally through the known forces.

It is unquestionable to me that the senses of bees are similar to those of men, and that especially the senses of sight, hearing, and smell play an important part. As Wundt has already shown, we certainly are "referred essentially to outer observations in animals; what they teach us is not a total dissimilarity in the capacity of mind, but the most essential conformity with the psychic processes which we observe in man, and which we know chiefly from observation of ourselves."[131] There is very great danger, therefore, of ascribing anthropomorphic characters to lower animals, and of applying human motives to them, or of comparing their motives with the higher human standards. Thus I can not agree with Lubbock's experiments on bees (l. c.) in so far as the proof of psychic faculties comes into consideration. The anthropomorphic method of treatment must lead the results astray. It is very characteristic of this method of treatment that Lubbock entertains great doubt as to the existence of a sense of hearing in bees, because he has played a violin, whistled, played a flute, and shouted before them, and never observed that they took the slightest notice. If, however, bees hear, they react only to such acoustic stimuli as have biological significance for them; for example, to the various sounds which they produce themselves.[132]

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[131] Wundt, Vorles. uber die Menschen und Tierseele, Leipzig, 1863, p. 318. In passing I wish to say that the bee community as pictured by Wundt (second edition, p. 453) contains many errors. I shall mention briefly here that the queen does not lay either fertilized or unfertilized eggs "from the beginning," and that the workers do not "carry a larva from the usual cell into an unoccupied queen-cell, where she is made a queen by good food." Bees are incapable of that. Just think of carrying a soft larva safely into a cell hanging down perpendicularly, and open beneath! The bee does it more comfortably by simply widening a worker-cell into queen-cell. These so-called "made-over" cells are always recognizable, for the floors show the prismatic joining of the worker cells, while the true queen-cell shows a round bottom. It is further incorrect, that the first queen to emerge remains in the hive while "the others issue with part of the workers." Just the opposite is the case. The facts about drones are also incorrect in part. Further, one can not disaccustom "the tame bees from swarming" "by enlarging the hive according to their necessity." Swarming is sometimes prevented by this enlarging; but a colony that has a "will" to swarm, swarms out of the largest hive. It is, therefore, not accurate to speak of "custom" or "disaccustom." Moreover, there are no "tame" bees. The views concerning robbing, also, do not tally with my observations. Wundt says that, as there is an instinct in bees to imitate, as, in fact, there is, we can conclude therefrom that "not every colony begins a new life, but that customs acquired in earlier generations can be communicated, not only through hereditary dispositions or organization, but also through the direct influence of the older bees upon the younger." I can not agree with this view. If memories last over the winter in exceptional cases (see p. 27) they nevertheless, no doubt, die out, on account of the short-liveness of the worker-bees (see p. 35), and the possibility of hereditary transmission is excluded too, because workers are sterile. The second possibility that individually acquired habits are transmitted through the influence of older bees on younger ones can, as well, not be accepted as true, as may be seen from what follows. It is an old bee-keeper's trick to introduce a very valuable queen in an absolutely safe way by establishing a colony of brood-combs with just-emerging bees to which the queen can be given immediately without further precautions. The young bees which were never with older ones behave in exactly the same way as others at once; they feed, gather, build, etc. Imitation or teaching by older bees is not present at all, yet the least difference from other colonies can not be noticed (see also Kogevnikow. Biol. Centralbl., 1896). As long as information about bees has existed, there has always been complete immutability. It is, therefore, not true that "we see under our very eyes such changes taking place in the habits of bees that there is no reason for not accepting the view that the characteristics of a hive have originated gradually, partly through hereditary physical abilities, partly through imitation of fixed habits.

[132] All further conclusions of Wundt's about the genesis of the bee colony (l. c., p. 455), since they depend in part upon "continuity with the past," can hardly be looked upon as conclusive. In the same way Wundt's theory of origin of instincts with reference to bees can not be supported; yet, as Wundt attempted, varying theories concerning instinct can be refuted satisfactorily upon the above basis. In the newest fourth edition of this work (1906) the greater part of the incorrect biological statements are omitted, but new errors are found upon which I can not here enter.

Compare herewith the interesting experiments Wm. M. Wheeler has made about the hearing capacity of ants already spoken of on p. 17.[133]

We obtain sure results in all these questions only by observing the conduct of the insects among themselves, or at least in experiments with artificially produced tones which approach those produced by the insects in question.

The anthropomorphic apprehension relative to the question of consciousness has brought it about that there has been ascribed to bees a consciousness similar to the human consciousness, and accordingly the most varied human feelings. In the settling of this kind of question the utmost caution must be used. On the basis of my observations I am of the opinion that bees possess either no consciousness at all, or one of only the lowest degree of development. The question of consciousness is left to subjective estimates; but the question whether an animal learns, and can acquire experience or not, may be determined objectively. The question is whether, in addition to the inherited (kleronome) nerve-paths, acquired (enbiontische) associations are formed (H. E. Ziegler). We see that bees show signs of an admirable memory in their orientation, and also in other activities;[134] further, I believe I have shown that the bee possesses a perception for color and form, and develops a rich capacity for communication by means of its well-developed "language;" that, further, it is able to gather experiences, to learn, and to form associations of impressions, etc. I can not agree with Bethe, therefore, in his denial that the bee has capacity to gather experience, and thereby to modify its actions (see p. 3). The bee is evidently much more than a reflex machine.

Zoological Institute, Oldenburg, i. Gr., 1906.

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[133] A clergyman, J. A. O'Neill, has discovered an interesting method for catching bee-ants (*Mutilla*) without difficulty. "This hymenopterous insect belongs to the musical ones. The male and female produce a clear sound which is caused by the rubbing of a sharp ledge on the third abdominal segment against a delicately furrowed triangular spot on the surface of the fourth segment. If one now finds a female mutilla and places it in his hand so that it can make this sound, the males in the vicinity come immediately, and are so fascinated that they sit on the hands of the capturer and can easily be seized (see L. Peringuey in the Jahrbuchern des Sudafrikanischen Museums; Reference in Prometheus, No. 540, 1900).

[134] Wm. M. Wheeler, Ethological Observations on an American Ant. Journal fur Psychologie and Neurologie. Bd. II. Heft 1 und 2. Berlin, 1903.

[135] Concerning the wonderful capacity for memory in bumble-bees, Ed. Hoffer, of Graz, submits an interesting communication in "Kosmos," Zeitschr. f. d. ges. Entwicklungslehre, XVIII. Bd., p. 111, Stuttgart, 1886. From that we learn that in the bumble-bees also, memories outlast the winter.

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